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COMBUSTION

JAN 7 1932

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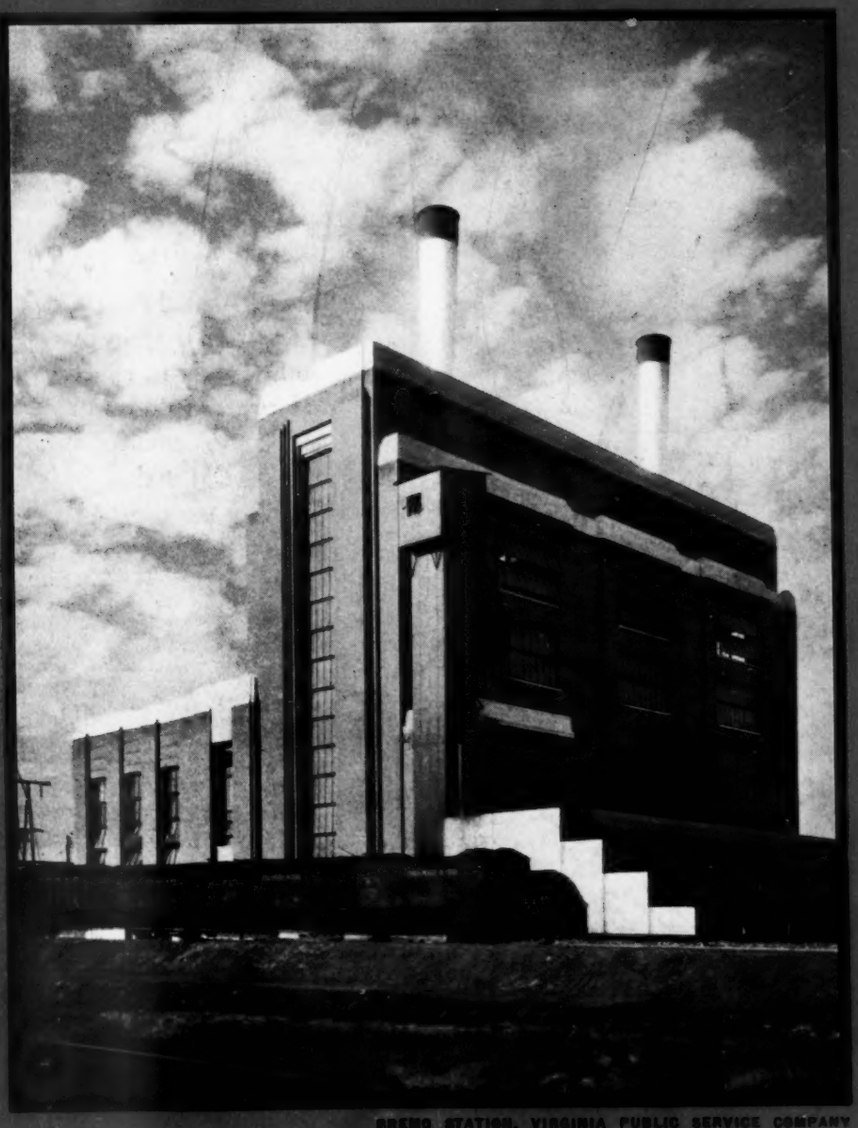


BREMO STATION, VIRGINIA PUBLIC SERVICE COMPANY

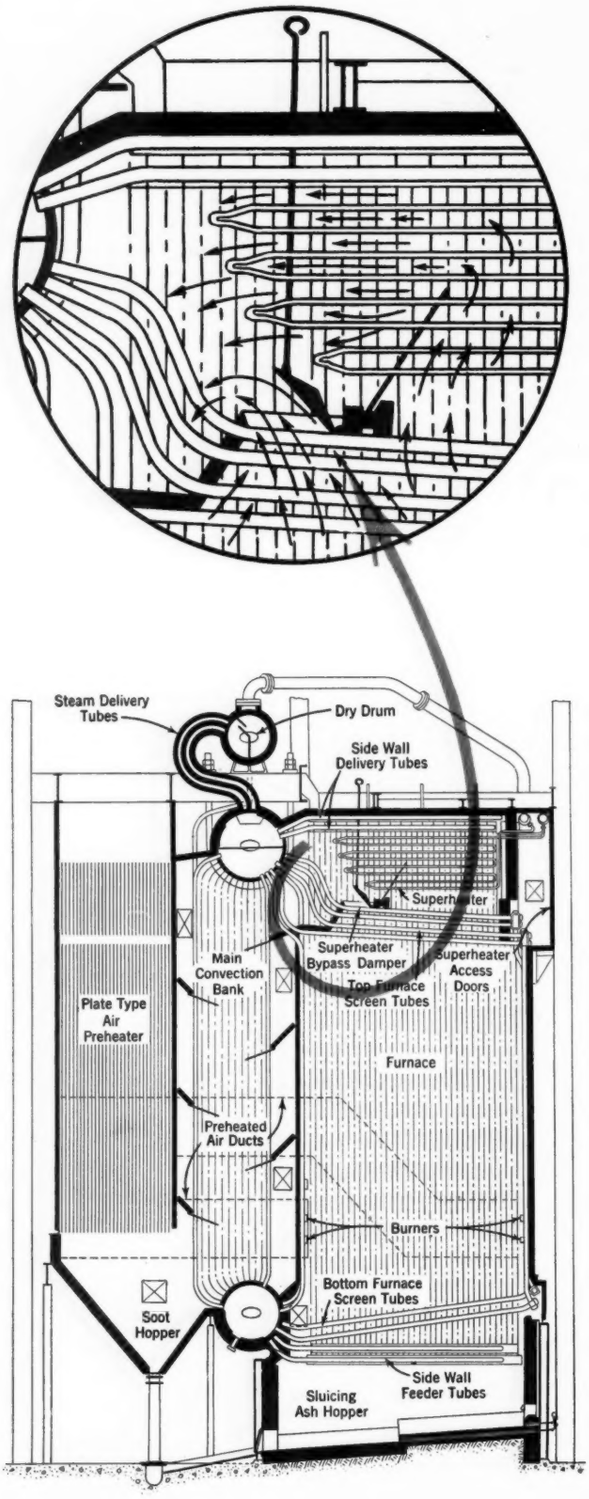
Corner Firing of Blast Furnace Gas
By OTTO de LORENZI

Ford Motor Company's 1200-Pound Steam-Plant Installation
By A. R. SMITH and H. B. HANSON

OTHER ARTICLES IN THIS ISSUE BY

EDWARD C. MATHIS • D. C. HORMELL • DAVID BROWNLIE • H. F. JOHNSTONE

CONTROLLED SUPERHEAT STEAM TEMPERATURE



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COMBUSTION

VOLUME THREE • NUMBER SEVEN

CONTENTS FOR JANUARY 1932

FEATURE ARTICLES

Corner Firing of Blast Furnace Gas	***by Otto de Lorenzi***	11
Ford Motor Company's 1200-Pound Steam-Plant Installation	***by A. R. Smith and H. B. Hanson***	17
Combustion Calculations from Gas Analyses	***by Edward C. Mathis***	25
Trend in Design of Principal Mechanical Equipment of Steam Stations	***by D. C. Hormell***	29
Coal Drying for Combustion	***by David Brownlie***	37
The Elimination of Sulphur Compounds from Boiler Furnace Gases	***by H. F. Johnstone***	40

EDITORIALS

New Possibilities of Pulverized Fuel 10
Dollar Efficiency 10

DEPARTMENTS

REVIEW OF NEW TECHNICAL BOOKS 47
NEW CATALOGS AND BULLETINS 48
NEW EQUIPMENT—Anti-Ambi Thermometer, Relay Pressure Valve, Boiler Manhole Blower, Valves 49
EQUIPMENT SALES—Boiler, Stoker and Pulverized Fuel 50
ADVERTISERS IN THIS ISSUE 55

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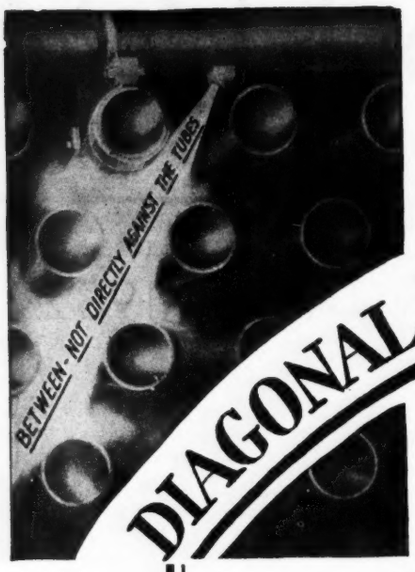

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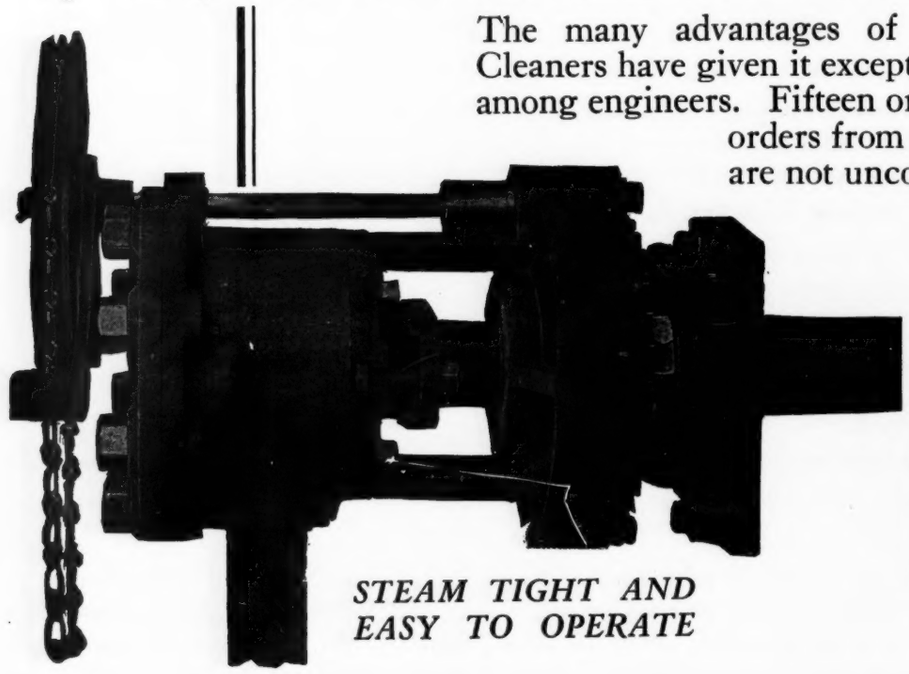

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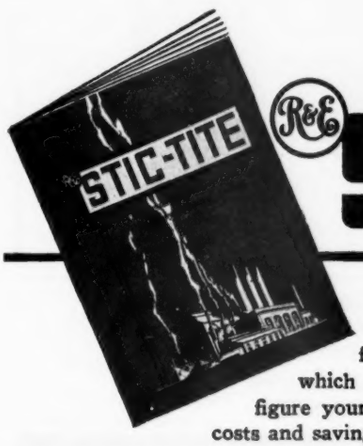

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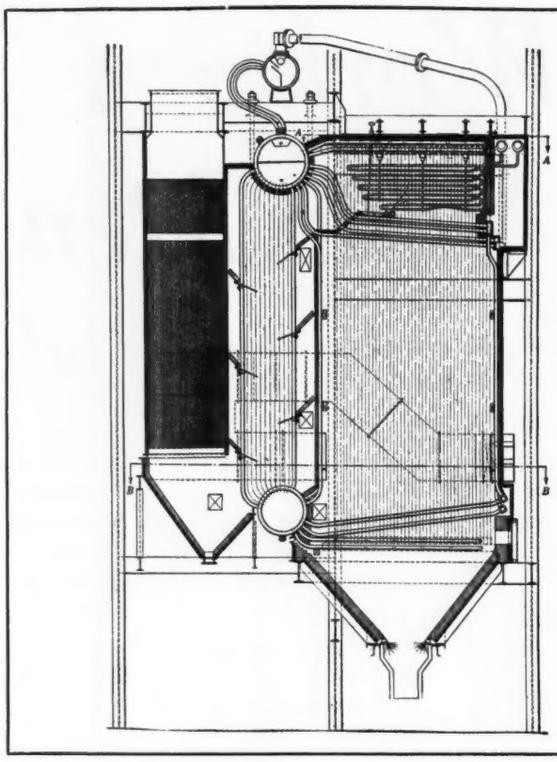

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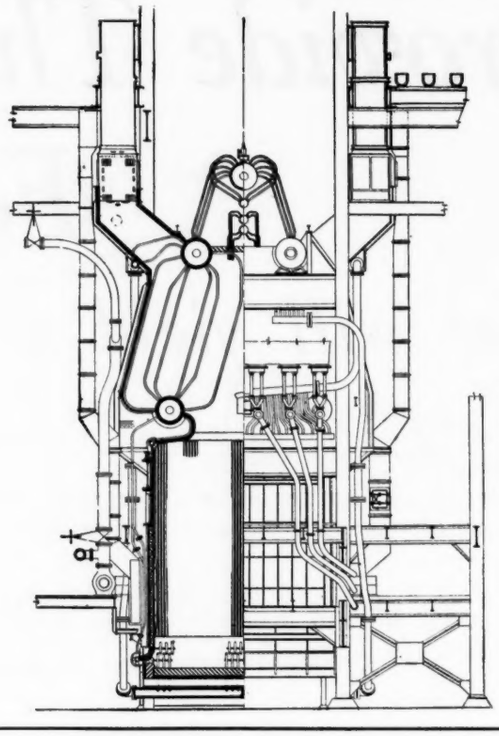

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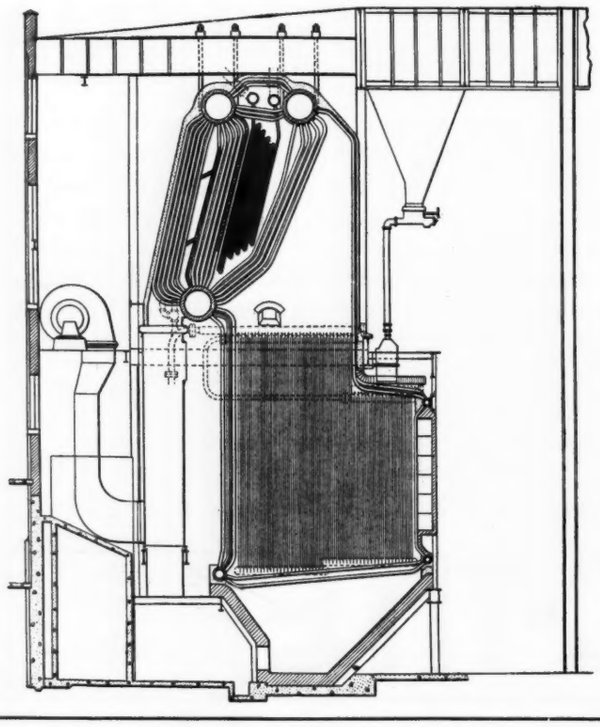

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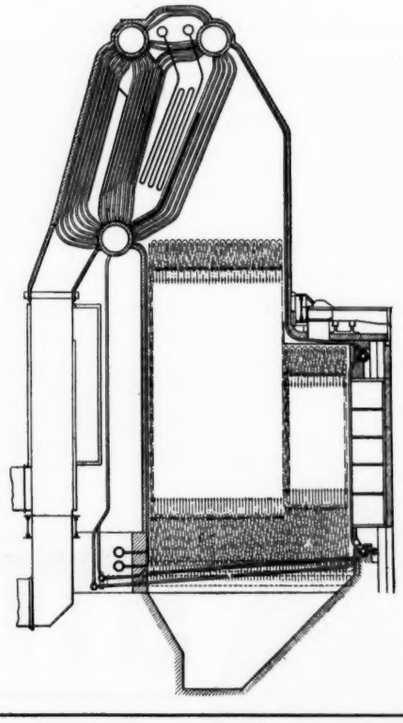

1390 lb. pressure
825 deg. total temperature
700,000 lb. capacity

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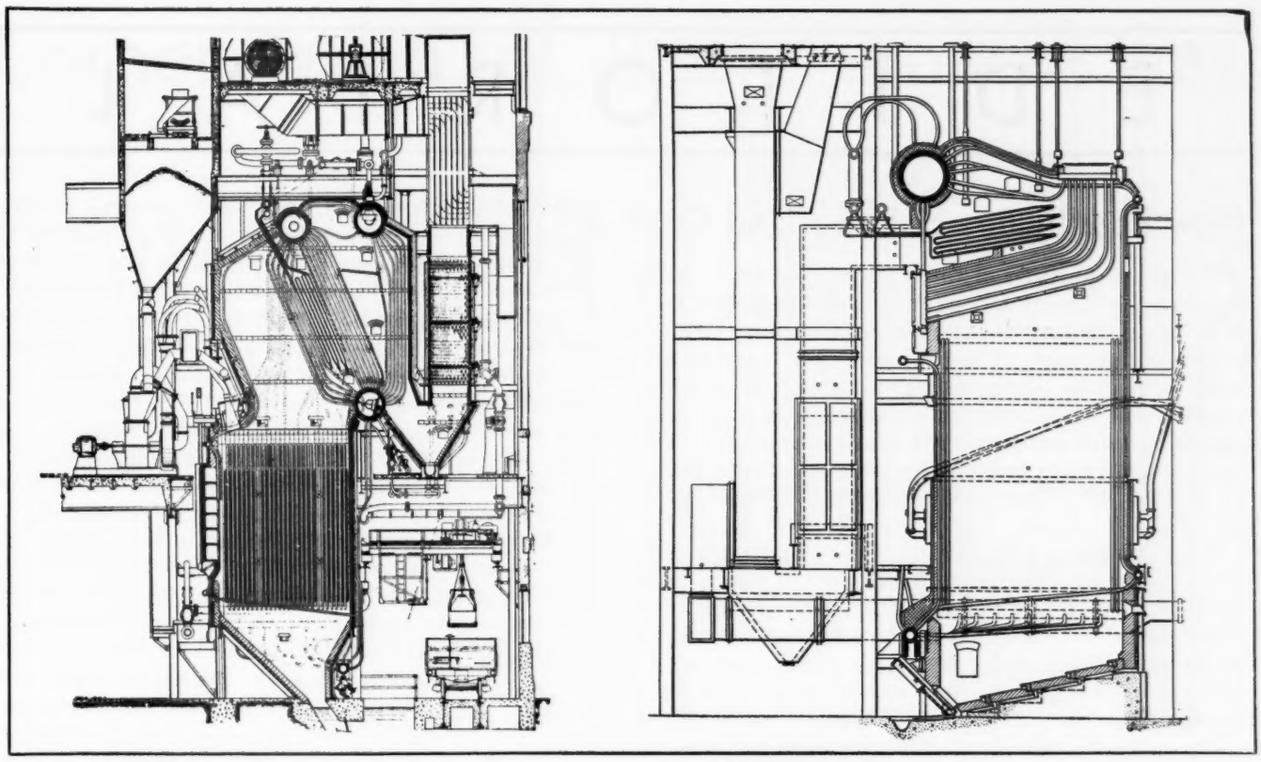

1350 lb. pressure
732 deg. total temperature
200,000 lb. capacity
Kansas City Pwr. & Lt. Co., Northeast Station

1840 lb. pressure
819 deg. total temperature
150,000 lb. capacity
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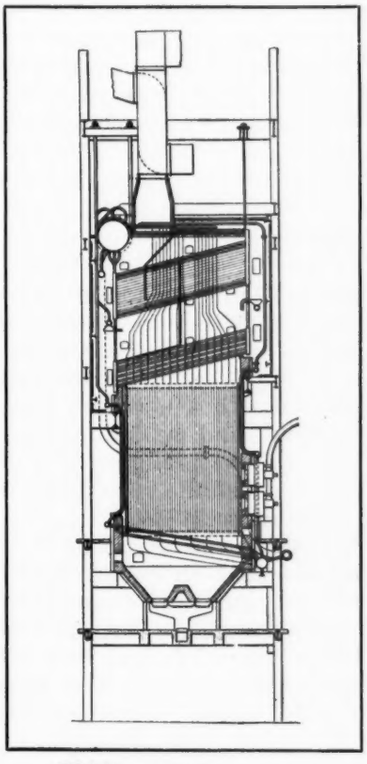

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EDITORIAL

New Possibilities of Pulverized Coal

COAL in pulverized form is proving itself to be an increasingly versatile and adaptable fuel. It is being used more extensively than is realized on ocean-going ships; it is taking a new lease on life with respect to locomotive application; it is being transported for considerable distances in pipe lines, specially built railway cars, and auto-trucks; and experiments have been made which indicate possibilities of its being used in engines of the Diesel type.

With respect to its use on ships, there are now at least seven European boats which have been operating with pulverized fuel successfully for more than a year. These include a tugboat, a dredger, and several cargo ships ranging up to 12,000 tons. Four of these vessels were converted to pulverized fuel firing and the others were originally equipped for it. Not only has the operation been satisfactory with regard to reliability, but considerable economies have been effected due to the higher efficiencies obtained and the lower-grade coals that can be used. In converted vessels, substantially higher ratings have been secured from the same boilers.

Two American freighters have been operating with pulverized fuel for a period of nearly two years with highly successful results. The operators of these ships have found that as compared to hand-fired vessels, the ships using pulverized fuel can carry 1800 tons more cargo at the same speed and consume four tons less coal per day.

Those familiar with this work are of the opinion that eventually pulverized coal will be favored over both hand-firing and fuel oil in the marine field except for the large luxury type of passenger vessel and naval ships.

With respect to locomotive application, much work has been done. In fact, more attention was paid to this field in the early days of pulverized fuel development than to stationary boiler applications. While considerable success was attained, certain difficulties were encountered (largely economic, due to cost of pulverizing plant) which in combination with conditions incident to the World War lead to the abandonment of the work. Since then a certain amount of development has been done, more or less intermittently, but nothing substantial has been accomplished until fairly recently, although a number of locomotives have been equipped not only in this country but also in South America and the Orient. This work has been taken up more actively since 1929 and interesting and highly promising experimental work has been done using the unit or direct-fired method of firing.

During recent years, considerable work has been done in Germany in the transportation of pulverized coal in pipe lines, railroad cars and trucks. The pneumatic method has been employed using suction up to distances of 450 yards and pressure up to 2000 yards. For greater distances it has been found that intermediate stations are required. As the result of this experience all the earlier difficulties have been overcome and definite figures are now available as to first cost per ton capacity per unit of distance, maintenance and operating costs.

German brown coal, which is very high in moisture content, is being pulverized at the mines and delivered in specially-built cars. The economics of this form of transportation indicate that small and medium size plants may effect savings by having coal delivered up to distances of approximately sixty miles. Complete data have been worked out for distances up to 300 miles.

It is not beyond the realm of possibility that pulverized coal may eventually find its way into the domestic heating field to challenge the competition of oil and natural gas. In fact, experiments along this line have already been made. Whether or not this market develops, there is no question that pulverized coal, which has only come into extensive use in the past decade, has definitely established itself as the most efficient form in which coal can be burned and is greatly broadening its field of usefulness. In this form coal has a large opportunity for regaining lost markets and preventing the further encroachments of other fuels upon its domain.

Dollar Efficiency

PRACTICAL engineering and economics have never been far apart and they are becoming more closely related all the time. While there have been many instances in plant design in the past where a sufficient distinction has not been made between maximum efficiency and maximum economy, engineers as a class are getting more "dollar-minded," a trend which is definitely reflected in present-day steam plant practice.

This trend is emphasized in the article by D. C. Hormell appearing in this issue. In tracing the development of the principal items of steam plant equipment over the past ten years, Mr. Hormell shows in every case that advanced designs have not only improved overall plant efficiency but have consistently reduced both initial and operating costs.

In the public utility field these improvements collectively have effected a reduction of 50 per cent in the average B.t.u. rate per kw. hr., and a reduction of 12 per cent in the cost of steam generating stations—achievements accomplished within the past ten years.

Corner Firing of Blast Furnace Gas

By OTTO de LORENZI
Combustion Engineering
Corporation, New York

•

Excellent overall results are being obtained with blast furnace gas in modern steam generating units designed for corner firing. The author briefly discusses developments in the use of this fuel for steam generating purposes and describes several units which typify the progress of the past few years. The test data presented show the advantages of corner firing as employed in steam generating units of the most modern design.

IN the modernized steel mill, turbo-generators provide the necessary power for operating motor-driven blowers and other equipment. This change has made available large quantities of blast furnace gas for the generation of steam, gas which was formerly burned in engines. The heat balance of the plant is such that sufficient gas is available for the major steam requirements, provided properly designed generating units are installed. There are times, however, when peak load requirements, or blast furnace operation, is such that it becomes necessary to burn supplementary fuel to meet the steam demands. In order to keep the number of steam generating units to a minimum, the furnace design must be such that the standby fuel may be efficiently burned, and the change over from one fuel to another must be accomplished without interruption to the steam output.

Blast furnace gas is slow to ignite and therefore difficult to burn quickly and completely. Because of the presence of large percentages of inerts, it is not an easy matter to mix the necessary air for combustion, and thus the time element is an important factor in the burning of this fuel. In the earlier designs of burners, the mixing of the fuel gas and air was practically left to chance. The result was incomplete combustion and extremely low efficiencies and ratings. For a while this was considered to be a necessary evil which was to be expected if the excess gas was to be disposed of by burning in boiler furnaces. As fuel costs began to increase, considerable study was given to the development of burner design, which would overcome the earlier difficulties experienced when burning blast furnace gas. Turbulence was recognized as the means for rapid mixture and resulted in higher efficiencies and ratings. This turbulence was secured, in most instances, by supplying the combustion air under pressure. To secure more thorough mixtures, a multiplicity of gas and air streams were projected into the furnace so that they intermingled and thereby set up a limited amount of turbulence. Combustion results were materially improved and it was possible to operate furnaces at higher ratings. The use of forced draft immediately made possible the more accurate control of the combustion air. By providing suitable regulation, and correctly proportioning the gas and air orifices, it was possible to vary the air supply in proportion to the gas flow and thus to confine the excess air within relatively narrow limits.

Coincident with burner development came the realization that furnace volume is a factor to be seriously considered. Best combustion results are secured when the furnaces are not forced too much. It is not only necessary to provide a certain furnace volume, for a given set of conditions, but the shape and disposition of the volume must be such as to make it entirely effective. Consideration must be given also to whether the gas is to be dry-cleaned or washed, as the dust content has an important bearing on the design not only of the burners but also of the furnace and boiler. Good practice indicates that with refractory furnaces and horizontal type burners, the liberation should not exceed 12,000 B.t.u. per cu. ft. per hr. when the gas contains more than 0.5 grain of dust per cu. ft. However, when the dust content is less than 0.5 grain per cu. ft., the liberation rate may reach as high as 18,000 B.t.u. per cu. ft. per hr.

The influence of the dust content of blast furnace gas, on furnace design, is considerable. The chemical composition of this dust is such that in the atmosphere of the furnace it may remain plastic and gummy at temperatures as low at 1400 deg. fahr. Because of this quality it becomes necessary to prevent, wherever possible, the flames from sweeping over high temperature refractory surfaces or accumulations of dust on the furnace bottom. If this is not done, sintering of these dust deposits, will occur and considerable labor must be expended to effect their removal. When sintering occurs on refractory wall surfaces, the resulting slag adheres tenaciously and the walls themselves may be seriously damaged when the deposits are removed.

To overcome sintering difficulties, water cooled wall surface was proposed. Due to the re-

duction in furnace temperatures, as a result of the addition of heat absorbing surfaces in the furnace, many steel mill engineers were skeptical. They reasoned that sufficient difficulties were being ex-

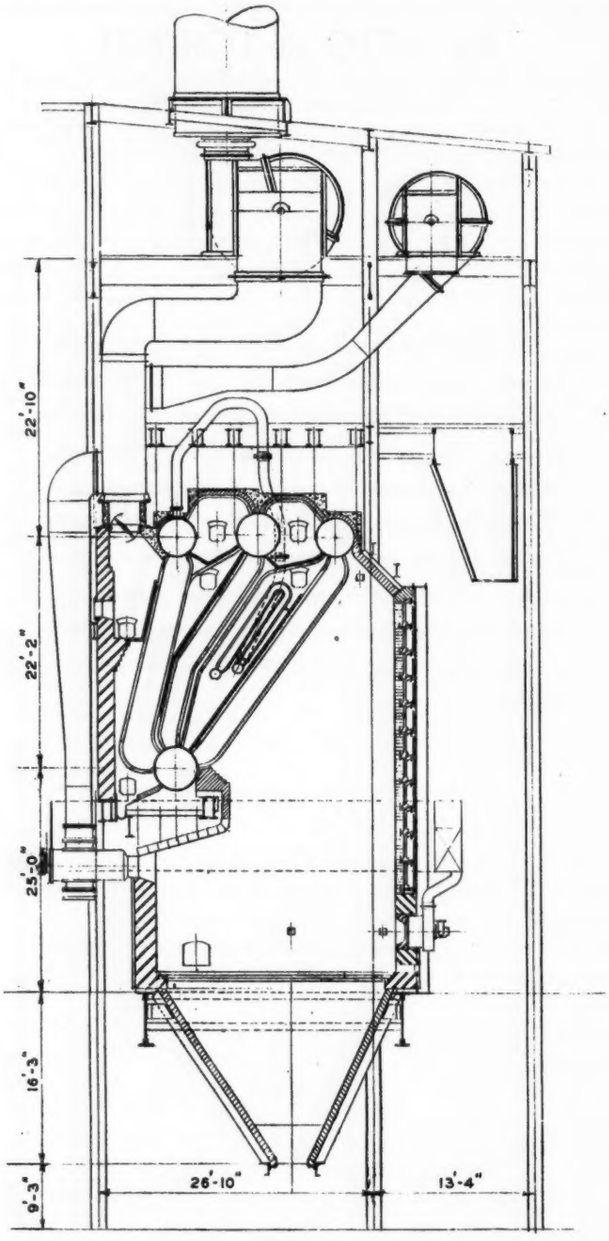

Figure 1.

perienced with ignition of the blast furnace gas in all-refractory furnaces. To lower the furnace temperature was courting danger. Notwithstanding these objections, an installation was made. The expected difficulties failed to materialize. In this instance bare, metallic water-cooled surface covered three quarters of each side wall and the entire rear wall. The hearth was shaded by bare tubes spaced on relatively wide centers. The extent of the water cooling was approximately 60 per cent of the total exposed wall area. In addition to this, there was incorporated still another feature which was contrary to the existing general practice. The gas burners, which were of the horizontal forced draft type, were set in a flush front wall instead of the conventional refractory "dog house." This installation has now been in operation for approximately four years. Its availability factor is considerably greater than that of the full refractory lined furnaces in the same plant. This high service factor exists notwithstanding the fact that the liberation in the water cooled furnace unit is from 18,000 to 20,000 B.t.u. per cu. ft., while only 12,000 to 14,000 B.t.u. in the refractory furnaces.

As pointed out in an earlier paragraph, increased turbulence, at the burner, was the means of increasing efficiencies and ratings. Refractory furnaces made it practically impossible to continue the turbulence in the combustion chamber, because of danger of flame impingement and sintering. However, by completely water cooling the furnace it became possible to carry on the mixing of the fuel gas and air, not only at the burner, but also in the furnace itself.

This additional mixing serves to speed up the combustion process and thereby reduce furnace volume requirements. Rates of heat liberation, in the furnace, of over 36,000 B.t.u. per cu. ft. have been maintained with high efficiency. Stratification has been eliminated and at the same time, it is

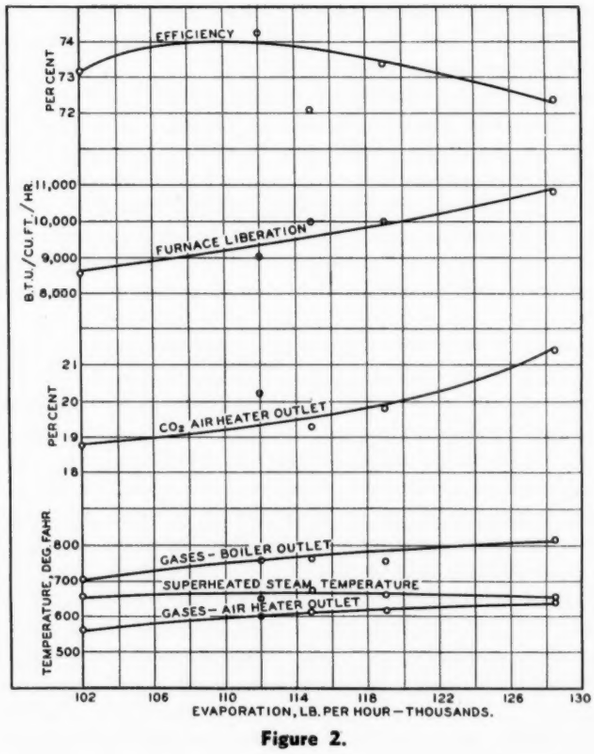

Figure 2.

possible to operate with very low percentages of excess air without secondary combustion occurring in the boiler passes. In installations of this type, highly preheated air serves to stabilize as well as to accelerate ignition.

The conclusions as to the efficiency of the method of firing, have been demonstrated, after several years of thorough trial, in a number of installations, in which the turbulent mixing of fuel and

air is continued in the furnace. However, comparative data will serve to clearly indicate the difference, in performance, between an installation using the standard horizontal type of burner and one using the turbulent corner firing method.

A blast-furnace-gas-fired steam generating unit as installed in a large steel mill, is illustrated in

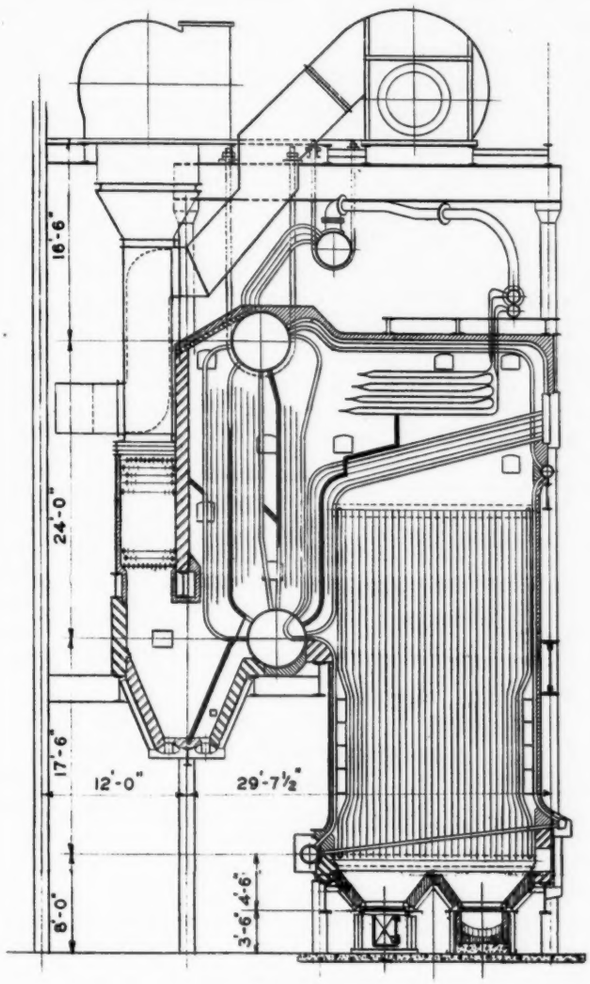

Figure 3.

Fig. 1. The boiler is of the conventional four-drum, bent-tube type, baffled so as to provide for three-pass travel of the gases over the heat absorbing surfaces. The superheater is located in the rear of the first baffle. The heating surface is 20,000 sq. ft. exclusive of the superheater. The boiler is provided with an air-cooled, refractory furnace containing 16,700 cu. ft. of effective volume. This furnace is 27 ft. wide, has a depth from front wall to bridge wall of 23 ft. and a height of approximately 35 ft. In the front wall of the furnace, are located four pulverized coal burners which serve to supply, as required, the standby or booster fuel. Three horizontal forced draft gas burners, of the Steinbart type, are located in a low wall just to the rear of and under the mud drum. A short arch forms the roof of this part of the furnace, and provides the necessary hot refractory surface to aid ignition at the burner. A plate type air preheater containing 18,060 sq. ft. of effective surface, is provided at the boiler outlet. The air for combustion is drawn, by the forced draft fan, through the lanes in the air cooled walls and then blown through the air heater. Ducts, from the heater outlet, serve both the pulverized coal and blast furnace gas burner.

A series of tests were run on this installation burning blast furnace gas alone, and also burning a combination of blast furnace gas and pulverized coal. Inasmuch as our interest is particularly in connection with gas burning, the first series of tests will be discussed at this time.

The performance of this unit, during the tests, is clearly shown by the chart, Fig. 2. A maximum evaporation of 128,500 lb. per hr. was obtained. The efficiency corresponding to this rating is 72.4 per cent and the liberation is 10,800 B.t.u. per cu. ft. of effective furnace volume. The gas burned contained from 0.3 to 0.5 grains of dust per cu. ft. and the moisture content varied from 15 to 30 grains per cu. ft. As indicated, on the chart, the efficiency at 114,850 lb. per hr. was only 72.1 per cent, due to the low CO_2 during this test. In plotting the curves the influence of this test has been heavily discounted so that the graphic results pre-

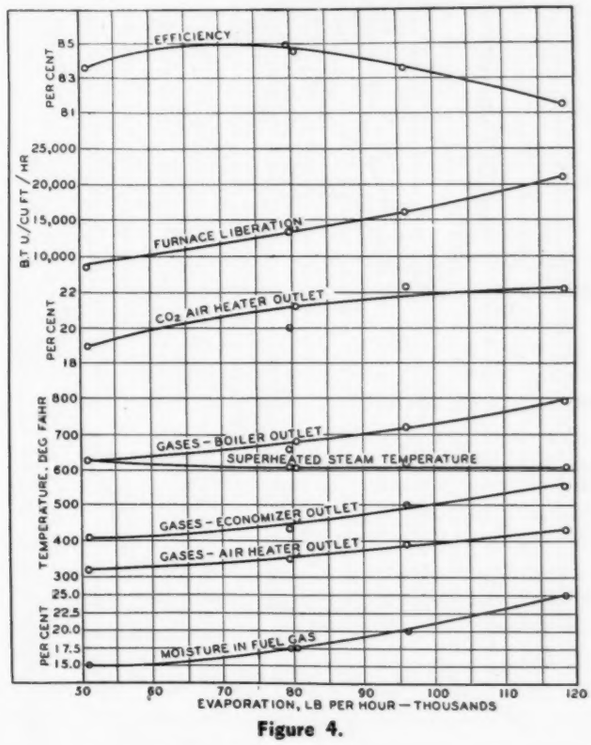

Figure 4.

sented truly indicate the performance of the unit over the range shown.

The steam generating unit shown in Fig. 3. is installed in one of the plants of the Bethlehem Steel Company. This unit contains many features which differ materially from the one shown in Fig. 1. The furnace is completely water cooled by heat absorbing surfaces, which form an integral part of the unit. The amount of surface exposed to direct radiation is 2790 sq. ft. The effective combustion

volume is 8,000 cu. ft. and the furnace is approximately 16 ft. wide by 16 ft. deep, with a height of 30 ft. A water screen is provided to shade the hearth and prevent sintering at this point. The superheater, with a heating surface of 2140 sq. ft., is located directly over the five rows of tubes above the furnace outlet. The boiler is of the two drum

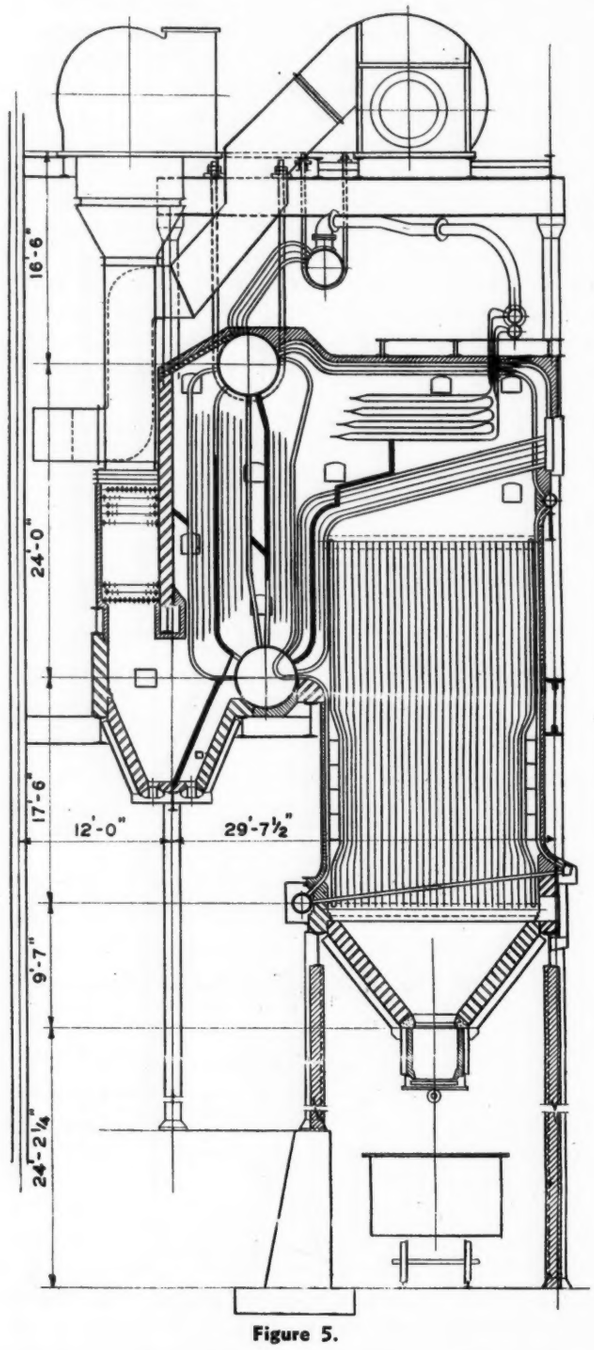

Figure 5.

type and contains 12,200 sq. ft. of surface. Baffles are arranged to provide three-pass travel of the gases over this surface before they enter the economizer. This economizer is of the fin tube type and contains 5382 sq. ft. of effective surface. Next comes a plate type air heater of 12,000 sq. ft.

The gas and coal burners are located in the four corners at the lower part of the furnace. They are so directed that the fuel streams form tangents to a small imaginary circle lying in the center of the furnace. By projecting the fuel and air into the furnace in this manner, a rotary motion is imparted to the mixture. Extreme turbulence is thus set up and thorough mixing is secured. The effect of this turbulence is to speed the combustion process materially and thus reduce the time required for completing the reaction. The rapidity with which complete combustion occurs, under these conditions, makes it possible to reduce the furnace volume materially.

The chart, Fig. 4., shows the performance of this unit during a series of carefully conducted tests. In this case the maximum evaporation was 118,000 lb. per hr. The corresponding efficiency was 81.5 per cent and the furnace liberation 21,800 B.t.u. per cu. ft. per hr. Washed gas, containing from 0.1 to 0.2 grains of dust per cu. ft. and 15 to 25 grains moisture per cu. ft. was burned. The maximum rating obtained was governed by the gas pressure and accumulation of dust in the burners. The minimum rating during these tests was 50,000 lb. per hr. with a corresponding liberation of 9500 B.t.u. per cu. ft. During normal plant operation, the output has been maintained as low as 25,000 lb. per hr. for long periods of time. The liberation corresponding to the rating is approximately 6500 B.t.u. per cu. ft. of furnace volume. This performance, when burning a fuel as lean as washed blast furnace gas, clearly indicates the ignition stability obtainable with corner firing.

The steam generating unit shown in Fig. 5, is installed in another plant of the Bethlehem Steel Company. The only difference between this and the one shown in Fig. 3, is the superheater, which contains 2651 sq. ft. and the ash hopper, which discharges into full size railroad cars instead of a sluice.

The chart, Fig. 6, shows the performance of this unit during a series of carefully conducted tests. As indicated, a maximum evaporation of 169,000 lb. per hr. was obtained. The efficiency corresponding to this rating was 80 per cent and the furnace liberation 31,285 B.t.u. per cu. ft. per hr. Washed gas, which was exceptionally clean, as it contained from 0.01 to 0.005 grains of dust per cu. ft., was burned. The moisture content of this gas varied from 10.6 grains per cu. ft. at the minimum rating to 21.5 grains at the maximum rating. At 107,000 lb. per hr., which was the minimum, during these tests, the furnace liberation was 18,825 B.t.u. per cu. ft. per hr. and the corresponding efficiency 85.30 per cent. The influence of extremely clean gas is well demonstrated when the results are compared with those obtained on the duplicate unit, using a somewhat dirtier gas. The fact that there was little or no tendency for the burners to accumulate mud deposits, made it possible to supply more gas to the furnace, without resorting to excessive pressures.

A careful analysis of the three units described, and the test results obtained, will clearly show

some of the many advantages of the extreme turbulence obtained with corner firing.

The unit shown in Fig. 1, has a total heat absorbing surface, including the air heater but exclusive of the superheater, of 38,060 sq. ft. The furnace volume is 16,700 cu. ft. The units shown in Figs. 3 and 5, each have a total heat absorbing surface, including the air heater but exclusive of the superheater, of 32,372 sq. ft. and the furnace volume is only 8000 cu. ft.

The first unit has a maximum efficiency of 74.0 per cent at 110,000 lb. per hr. evaporation. The efficiency drops off to 72.3 per cent at the maximum rating of 128,500 lb. per hr. The second unit described, has a peak efficiency of 85 per cent at an evaporation of 72,000 lb. per hr. The efficiency then drops off to 81.4 per cent at 118,000 lb. per hr. The third unit has a peak efficiency of somewhat over 85 per cent, occurring between 80,000 and 90,000 lb. per hr. evaporation. The efficiency then drops off to 79.8 per cent at 170,000 lb. per hr.

The unit shown in Fig. 1, as previously mentioned, has a furnace width of 27 ft. The distance between center lines of outside columns is 36 ft. The height of the ash hopper is 16 ft. 3 in. The distance from the ash hopper supporting beam to the fan floor is 70 ft. The depth from front to rear of the bay is 40 ft. 2 in. The total building volume, occupied by this unit, from the ash hopper discharge to the fan floor, is 124,750 cu. ft. Of the above volume 23,550 cu. ft. is required for the ash hopper and the remainder for the unit. Because of the absence of suitable cooling means, it is necessary to provide a sufficiently large hopper for the dust accumulation. Sintering is thereby minimized as the deposits are not directly swept by flames. A bare tube water screen placed across the hearth would make it possible to materially reduce the size of the refuse receiving hopper.

In Fig. 3, the unit shown has a furnace width of 16 ft. 2 in. The distance between centerlines of outside columns is 26 ft. The ash hopper height is 4 ft. 6 in. The distance from center line of the lower rear header to the fan floor is 58 ft. The depth of the bay from front column to rear column is 41 ft. 7½ in. The total building volume, occupied by the unit, from fan floor to ash hopper discharge, is 67,700 cu. ft. The refuse hopper in this case requires 4875 cu. ft. of the above volume. The use of the bare tube water screen across the hearth makes possible this shallow ash pit. In order to prevent the dust accumulation from building up, it is necessary to remove it at twelve hour intervals. This, however, is easily accomplished as pressure water jets and a sluice are provided.

The unit shown in Fig. 5, except for the ash

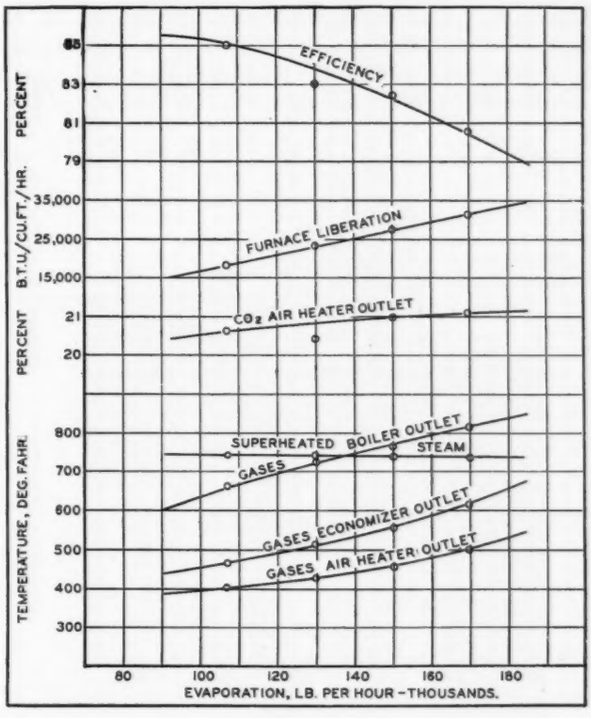

Figure 6.

hopper, requires the same building volume as the one shown in Fig. 3. The total volume in this case is 73,000 cu. ft. The volume required by the refuse hopper is 10,175 cu. ft. In this particular installation the customer desired sufficient storage capacity, below the hearth screen, so that the accumulations need only be removed at weekly intervals.

The foregoing comparisons, of building volumes, are particularly significant, when the maximum output, as well as efficiency obtainable, are recalled. These figures indicate that a saving of approximately 40 per cent is possible when corner-fired units are used. This saving does not take into account the various refuse hoppers shown, but

TABLE I—COMPARISON OF UNITS SHOWN IN FIGS. 1, 3 AND 5

	Unit, Fig. 1	Unit, Fig. 3	Unit, Fig. 5
Heating surface, boiler and furnace ..... sq. ft.	20,000	14,340	14,340
Heating surface, economizer ..... sq. ft.	.....	5,382	5,382
Heating surface, air heater ..... sq. ft.	18,060	12,000	12,000
Total heat absorbing surface ..... sq. ft.	38,060	31,722	31,722
Furnace volume, effective ..... cu. ft.	16,700	8,000	8,000
Maximum liberation on tests ..... B.t.u. per cu. ft.	10,800	21,800	31,285
Efficiency at maximum rating ..... per cent	72.40	81.50	80.0
Maximum evaporation on tests ..... lb. per hr.	128,500	118,000	169,000
Building volume required by unit above ash hopper ..... cu. ft.	101,200	62,825	62,825
Building volume required for ash hopper ..... cu. ft.	23,550	4,875	10,175
Total building volume from ash hopper discharge to fan floor ..... cu. ft.	124,750	67,700	73,000

represents what can be done with the steam generating unit itself. The type and size of ash pit, is a matter of particular plant requirements. Data of these three units are given in Table I.

Since the installation of the units in Fig. 3 and Fig. 5, there has been developed another design which is somewhat simpler. The illustration, Fig. 6, indicates the general outline of this new steam generator. The particular unit illustrated is designed for coal firing. For blast furnace gas firing, the lower end of the air heater is removed and a suitable economizer substituted. Where somewhat

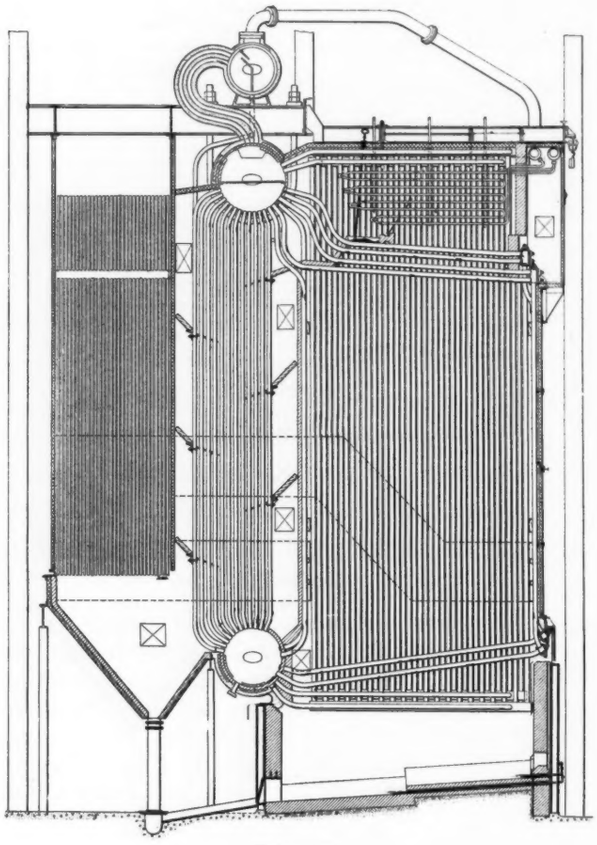

Figure 7.

lower efficiencies are acceptable, it is not necessary to install the economizer, but simply use the unit as shown. These units are built in a series of standard sizes with approximate capacities ranging from 60,000 to 300,000 lb. per hr. The construction includes a sluicing type of ash hopper and thereby reduces building height requirements to a minimum. Unlike other types of water-cooled furnace units, all downcomer and riser connections are inside the setting, and form part of the active heat absorbing surfaces. A superheater by-pass damper is provided so that it is possible to regulate or maintain a uniform steam temperature over a relatively wide range of loads. The main convection bank consists of tubes closely spaced. The gases make one pass over this surface. This feature eliminates the dust pocket usually present when more than one gas pass is required. A large dust or soot hopper is provided between the gas outlet of boiler and inlet to the economizer or air heater.

The tests and installations described, indicate that it is possible to effect major operating economies in the burning of blast furnace gas. The corner-firing method, applied to water-cooled furnaces, of the bare tube wall design, is the means available.

When burning washed gas, saturated with water vapor and carrying 0.1 to 0.2 grains of dust per cu. ft., it is necessary to clean the burners at intervals. When the washing of the gas is such that the dust content is not over 0.05 grains per cu. ft., the burners require practically no attention. With dry scrubbed gas, having as much as 2 to 3 grains of dust per cu. ft., no burner difficulties are experienced. The dust in this case is deposited in the refuse hopper at the bottom of the furnace. These hoppers must then be emptied, at sufficiently frequent intervals, to prevent the dust deposits from extending into the zone where sintering occurs.

The use of the bare tube wall design increases the availability factor of this type of unit. Slag and sintered dust deposits may form on these walls. However, they continually fall into the shaded refuse hopper before their size renders them troublesome. The self cleaning feature, of this type of wall, removes the major source of outage which is so troublesome in the refractory lined furnace.

The use of bare, water cooled, metallic furnace linings reduces maintenance costs to a minimum. There are no refractory surfaces to be washed away by molten slag. There are no surfaces to which sintered dust may cling, so tenaciously, that damage results when these deposits are removed.

The application of corner-firing has made it possible to reduce the furnace volume requirements by 50 to 60 per cent for a given output. The furnace walls are extremely efficient heat absorbers and form an important element in the design of the new type unit. The temperature of the gases leaving the furnace is lowered because of the large amount of heat given up to the walls. This reduction in temperature is advantageous as the tendency for "birdnesting," of the boiler tubes, is reduced.

These new types of units are compactly designed and the required building volume is kept to a minimum. The smaller furnace requirements and the water-screen-shaded ash pit, with its reduced volume, are important factors in bringing the size of these units down to a point where they compare favorably with those designed for coal firing.

Throughout the steel industry efforts are being made to reduce production costs. The fuel cost, per ton of finished steel, is a very small item in itself. However, the total number of dollars that it is possible to save, yearly, may be advantageously employed to effect further economies in other parts of the mill. Blast furnace gas, even though it is a by-product, represents a definite fuel investment. To secure the maximum return, it is necessary to provide modern and efficient equipment. The corner-fired steam generating unit has demonstrated its capacity, efficiency, and reliability and, therefore, merits serious consideration.

Ford Motor Company's 1200-Pound Steam-Plant Installation*

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This paper, presented at the recent A.S.M.E. Annual Meeting, describes the general features of the 110,000-kw., 1200-lb. pressure, turbine-generator installation in the Ford plant at River Rouge. It is interesting from the standpoint that it is an industrial power plant; that it replaces and occupies no more space than equipment which had only one-eighth this capacity; and that the change has been made without interruption of service, and with little or no exterior evidence of such a complete rehabilitation . . . A discussion of this paper was presented by Henry Kreisinger in which the two high-pressure steam generating units are described in detail. This discussion is also printed in full in these pages as a supplement to the paper.

THE major apparatus in the main steam power plant in the River Rouge factory of the Ford Motor Company consisted of four boilers of 250 lb. steam pressure, 600 deg. fahr., 250,000-lb. capacity, and four similar boilers which had been rebuilt and modernized two years ago, to have a capacity of 500,000 lb. each. The turbine equipment consisted of four 30,000-kw. units and two 12,500-kw. units. It was decided to increase the generating capacity by substituting larger units for the 12,500-kw. turbines and to reconstruct that half of the turbine room where these units were located to get the maximum turbine capacity possible consistent with high efficiency and proper operating conditions. The plan finally selected provided for two 110,000-kw. turbines in that space, one of which has been installed and is now in operation.

The capacity of the plant is now one 110,000-kw. turbine, four 30,000-kw. turbines, two 30,000-kw. Detroit Edison tie-lines totalling 290,000-kw. with provision for a second 110,000-kw. turbine. The electrical system which carries a potential of 13,800 volts is divided into four sections, each bus section being connected through current-limiting reactors to a common synchronizing bus. There will be connected to each section of bus one-half of the capacity of each 110,000-kw. turbine generator and one 30,000-kw. turbine, while the Edison tie-lines will be connected to the synchronizing bus.

The existing crane span limited the overall length of the turbine, as the crosswise arrangement of turbine indicated the greatest economy of floor space and the best circulating-water connections. This suggested the use of generators of equal capacity, while the substantial concrete mat and the limited floor area suggested the use of the steeple-compound turbine. The complete turbine-room equipment including steam reheaters, boiler feed pumps and all turbine accessories has a content of 3.16 cu. ft. per kw. when counting all the space between the basement floor and the roof trusses, but not including the switching galleries.

The prevailing steam conditions were not conducive to very high economies and inasmuch as four of the boilers were to be completely remodeled to increase their output, it seemed logical to resort to 1400-lb. steam pressure. This higher steam pressure, aside from its economic advantage, was of great importance because of the then limited supply of condensing water, or the possibility of reducing the size of the tunnel under consideration and since constructed. The possibility of ultimately providing extraction steam for general process work in the factory was another consideration for using a higher steam pressure.

The boilers, which were to be rebuilt, unfortunately were the ones farthest from the turbine room, which made the run too long and the space too limited for boiler reheat piping. The division of the turbine capacity into two equal parts meant a low cross-over pressure, 70 lb. gage, and boiler reheat was not advantageous, whereas steam re-

* Presented at the Annual Meeting of the A. S. M. E., New York, Nov. 30 to Dec. 4, 1931.
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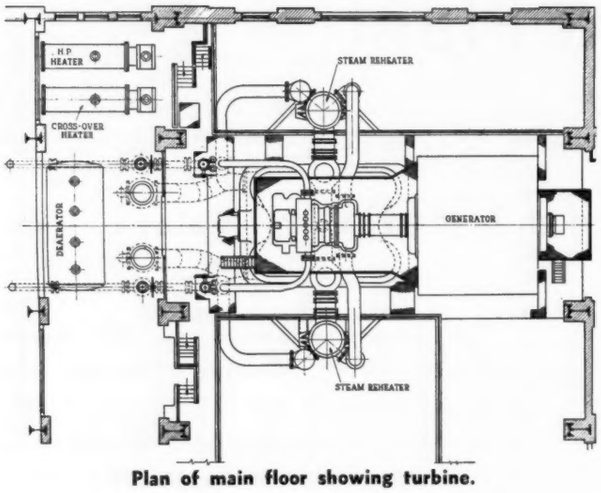
heat served the purpose admirably. A reheat temperature of 500 deg. fahr. was selected as being the uppermost limit possible without resorting to thoroughfare reheaters, the economy of which was

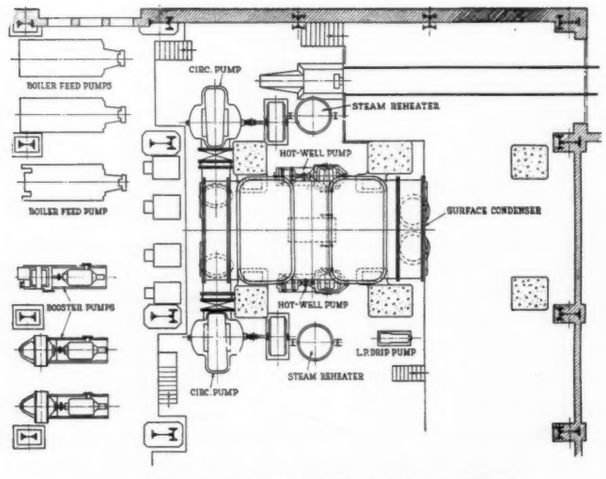


Plan of main floor showing turbine.

considered questionable and the space, which would be required, objectionable.

Boilers

The two new boilers, which occupy the same space as two of the 250,000-lb. boilers, are of the double-set, bent-tube type, with two lower, two upper, and one dry-steam drum, each boiler having a capacity of 700,000 lb. per hr. The furnace is completely water cooled with bare finned tubes constituting a heating surface of 5,234 sq. ft., while the bottom is provided with a dry-ash water screen containing 770 sq. ft. of surface. The furnace vol-



Plan of lower floor showing turbine auxiliaries.

ume is such that the heat liberation will be 27,000 B.t.u.

Four motor-driven forced-draft fans and two motor-driven induced-draft fans are provided for each boiler and are located immediately above the boiler. Economizer surface of 14,000 sq. ft. and air preheaters of the plate type with a heating surface of 64,800 sq. ft. per boiler will, it is expected, bring the overall boiler efficiency up to 86.5 per cent.

The fuel-burning equipment will provide for burning a considerable amount of blast-furnace gas along with the pulverized coal which is the basic fuel.

Turbine Generator

The high-pressure turbine is built for 1200 lb., 725 deg. fahr. temperature, and the steam exhausts at 70 lb. gage, with approximately 5 per cent moisture content at maximum output. This steam is reheated to 550 deg. fahr. and passes through the low-pressure turbine exhausting to the condenser. Steam is extracted at 288 lb., at the 80-lb. crossover, at 28 lb. and 8 lb. absolute for heating the feedwater to a temperature of 406 deg. fahr., and for evaporating some makeup requirements. The high-pressure turbine has 12 stages, the first stage being a double-row Curtis wheel with partial admissions. The low-pressure turbine has 10 stages and is double flow. Both units operate at 1800 r.p.m. and are of approximately equal capacity depending on the steam conditions, amount of steam extracted, and other variable features. No provision is made for operating either unit without the other.

The two generators are of the same design and capacity and each is provided with a double winding; each winding being permanently connected to the corresponding winding on the other generator. Consequently both turbines will contribute their proportionate share of work according to the steam conditions and regardless of the load demand on any section of the main bus.

The two generators are built into a common structural frame and are self-ventilated by means of fans on the shafts, each generator having its own air circuit and self-contained surface coolers.

The turbine design is simply a superimposition of the high-pressure turbine on the low-pressure turbine, the temperature influence on the alignment being reduced to a minimum by introducing a cast-steel stool, to support the high-pressure turbine. The small size of the high-pressure turbine permits the use of an unusually long flexible connection between it and the generator. The high-pressure turbine and the supporting stool are removed bodily when it is necessary to dismantle the upper half of the exhaust casing.

Condensing Equipment

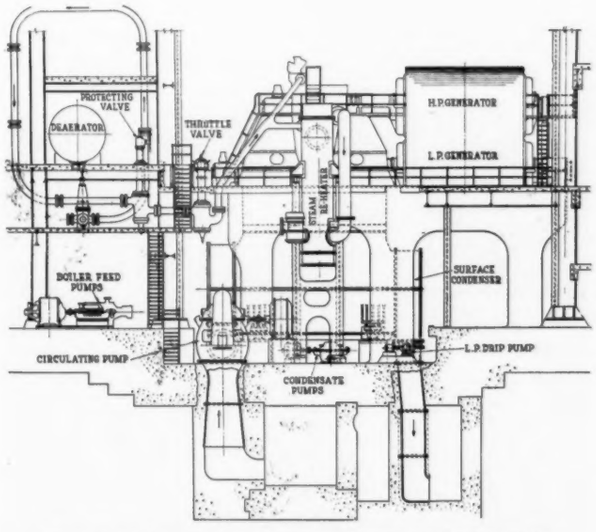
It will be observed that the condenser parallels the shaft, a practical arrangement because of the double-flow turbine and its two exhausts. An expansion joint of rubber was provided between one of the exhausts and the condenser casing so as to take up any differential expansion between the center lines of the turbine exhaust and the center lines of the condenser inlets, otherwise the condenser is solidly connected to the turbine and rests on spring supports having the usual loading characteristics.

The complete absence of condensing-water piping was one of the factors contributing to the reduction of space requirements. The two circulating pumps have their suctions at the bottom and are located over the intake tunnel, while the condenser discharge is carried out at the bottom of the opposite water box, this being a single pass condenser directly down into the discharge tunnel. A partial weir effect inside the discharge water box prevents the uppermost tubes from remaining dry. The somewhat limited size of the existing condensing-water tunnels emphasized the necessity of careful design in the form of stream-line flow for both the pump sections and the condenser discharge.

The condenser contains 77,000 sq. ft. of cooling surface. The tubes are 28 ft. 3 in. long, 7/8 in. in diameter. They are rolled at one end and packed at the other, but floating tube support plates are arranged so that tubes can be rolled on the packed end should the packings show signs of troublesome leakage.

Reheaters

The steam reheaters are of a somewhat new design in that each consists of a single bundle of straight tubes with a floating head at the bottom. The 1200-lb., 725 deg. steam enters at the top steam chest, flows down through the tubes and the condensate is removed from the bottom chamber. The exhaust steam from the high-pressure turbine enters at the lower end of the reheater shells and circulates radially in and out about concentric baffles till it reaches the top, thus forming almost perfect

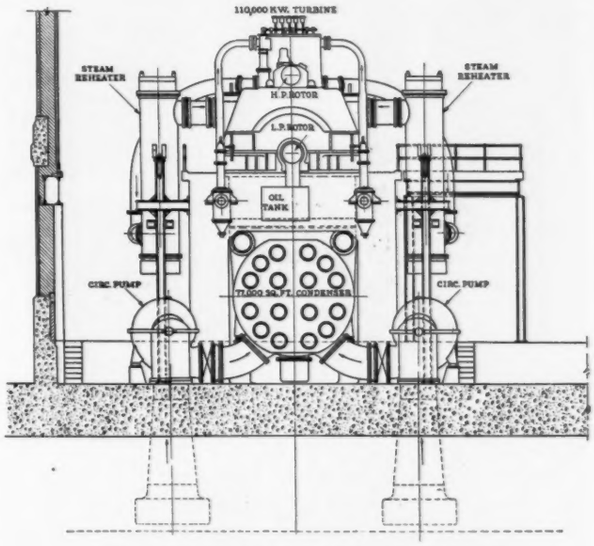


Elevation showing turbine, condenser and auxiliaries.

counter flow with the heating steam. The two reheaters have a total heating surface of 16,300 sq. ft. which is made up of tubes 20 ft. 9 in. long, 3/4 in. outside diameter, and having a composition of chrome-vanadium steel.

The reheater support is carried down to the basement floor, so as to provide freedom of motion to and from the turbine as the temperature of the unit and its piping changes. The weight of each reheater is 36 tons. The use of corrugated expansion joints turned out of solid rolled-steel stock for the connecting piping is somewhat novel and this is especially true of the connection between the reheater shell and the floating condensate chamber, which greatly simplified the drainage problem.

The condensate from both reheaters is carried to a common drainage vessel at full pressure, which



Sectional elevation of turbine and condenser.

is arranged with a float control to regulate the discharge which then passes through a cooler to depress the condensate temperature 40 deg. fahr. before it enters the intermediate stages of the main feed pumps.

Deaerator and Heaters

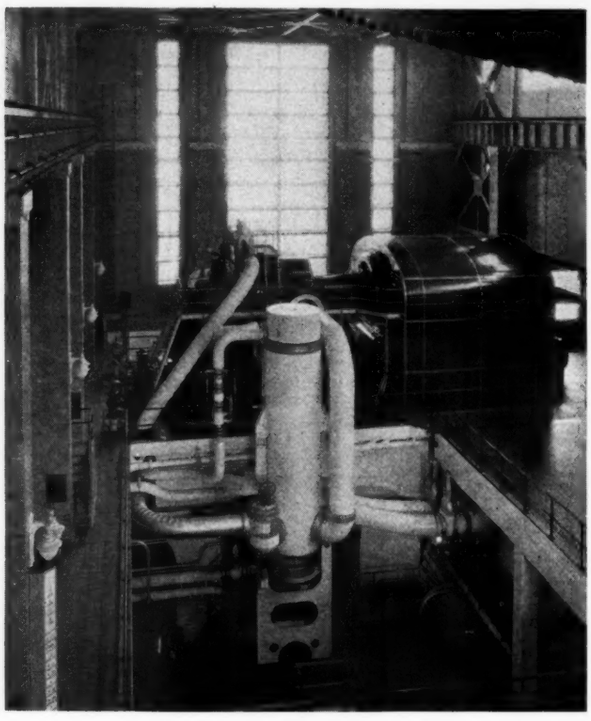
The low-pressure heater, the one connected to the crossover and the high-pressure feedwater heater are of the usual floating-head, horizontal type, but the heater operating at 28 lb. absolute is of the direct-contact type, provided with suitable deaerating equipment and considerable water storage, as it serves as a supply to the main booster pumps. The purpose of this additional deaeration over and above that which the condenser provides was to protect against the possible reabsorption of air through flanged joints and stuffing boxes, operating below atmospheric pressure, and to give a somewhat higher degree of air-free condensate than the condenser might afford.

The accompanying diagram will illustrate the heat balance which is of the usual design. The drainage of the low-pressure heater is pumped ahead to conserve heat, and it was concluded that the high-pressure heater drainage should be pumped ahead to conserve heat and horsepower, but the impracticability and excessive cost of the pump made it necessary to abandon the scheme.

Feed and Booster Pumps

There are three booster pumps, each having capacity of 700,000 lb. of water per hour when receiving their suction from the deaerator heater at

a pressure just above atmospheric and pumping against a head of 750 lb. There are three feed pumps, each having a capacity of 800,000 lb., which take their suction at 750 lb. and deliver it to the main boiler feed header at 1500 lb.



Photograph of turbine and condenser.

Both booster and feed pumps operate at 1800 r.p.m. and have six stages. Two of the three booster pumps and two of the three feed pumps are motor driven, while the third unit in each case is turbine driven. Under normal conditions the two motor-driven feed pumps and the two motor-driven booster pumps will serve the 1200-lb. boilers, but in the event of the loss of water pressure in the 1500-lb. feed header, the turbine-driven feed pump automatically comes into service and in the event of the loss of pressure on the 750-lb. header, the turbine-driven booster pump automatically comes into service.

The temperature of the water to the booster pumps is 240 deg. fahr., but the water is heated again at the 750-lb. header so that the feed-pump suction water is 406 deg. fahr. Both feed and booster pumps are provided with labyrinths for breaking down the pressure against the final packing, and in the case of the feed pumps, the high temperature is avoided by supplying the labyrinth leakage by two separate motor-driven reciprocating pumps which get their supply at 75 deg. fahr. temperature. In the event of failure of this labyrinth supply pump, the flow would be in the opposite and usual direction and temporarily the pumps would have to withstand the higher temperature.

All four motor-driven pumps are provided with variable-speed control to the extent of 15 per cent below synchronous, so as to hold as nearly as possible the required water pressure for varying temperatures, pump outputs, and boiler requirements. This pressure regulation is automatically controlled and it serves two purposes; first, the reduction of auxiliary power consumption, and second, the minimum stresses on piping and other equipment which, if unregulated, might be excessive.

Piping

The high-pressure steam and water piping is all of the Sarlun design with somewhat thicker flanges. Two quick-acting valves similar to the turbine automatic stop valves furnished as a part of the turbine unit have been provided for extreme emergency operation and are located on the boiler side of the turbine-room wall.

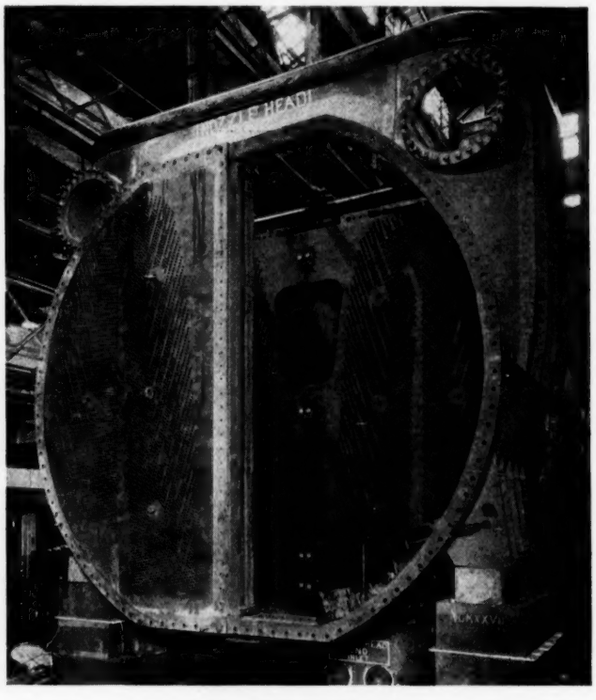
Electrical Switchgear

The concentration of power, far in excess of that contemplated when the switchgear was originally installed, obviously necessitated a complete rehabilitation which has been accomplished in the most ingenious manner in the original space, and the change over now well made involved no suspension of operation.

Iron-clad oil circuit breakers, iron-protected bus bars and iron-clad feeder reactors give protection to human life, protection against accidental short circuit and trouble from conductible gas and reduction in fire hazard, and also gives a new conception of switchgear design in the form of complete mechanical units, factory built and interchangeable.

Foundation

The turbine foundation is constructed of concrete exclusively and is of extremely simple lines.



Cross section of condenser.

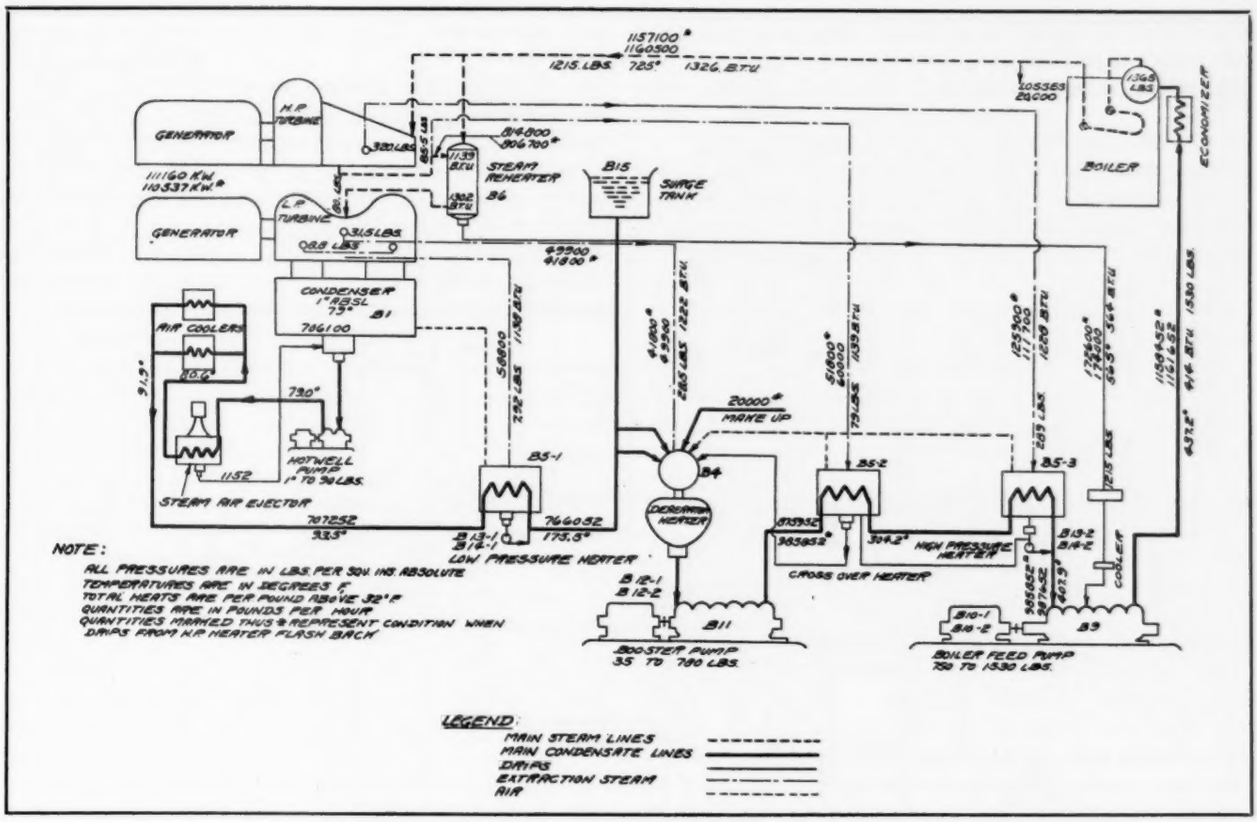


Diagram of heat balance for 110,000 kw. turbine unit.

The symmetrical positions of the six piers, made possible by the use of the steeple-compound turbine, forms a very substantial structure without occupying much basement floor space. All of the edges are rounded to 4 in. radius and all arches are curved, which appreciably adds to the appearance and minimizes mutilation.

Condensing-Water Tunnel

The condensing water and the factory manufacturing water were formerly obtained from the River Rouge, the flow of which during certain periods was practically nil and frequently dirty, a condition which was unsatisfactory for both condensing and manufacturing purposes. The maximum condensing-water requirement will be about 366,000 gal. per min. and manufacturing will ultimately require almost as much.

A tunnel has been constructed from the Detroit River to the plant, having a capacity of 630,000 gal. per min. and the River Rouge will serve to return the water back to the Detroit River. This will result in an ample supply of clean, cool water and assist in flushing River Rouge in dry periods.

The former intake from the River Rouge now becomes a discharge and parallels the former discharge, but should anything happen to the new tunnel, its intake, or its pumps the former intake automatically reverts to original service and the previous unsatisfactory condition must be tolerated temporarily.

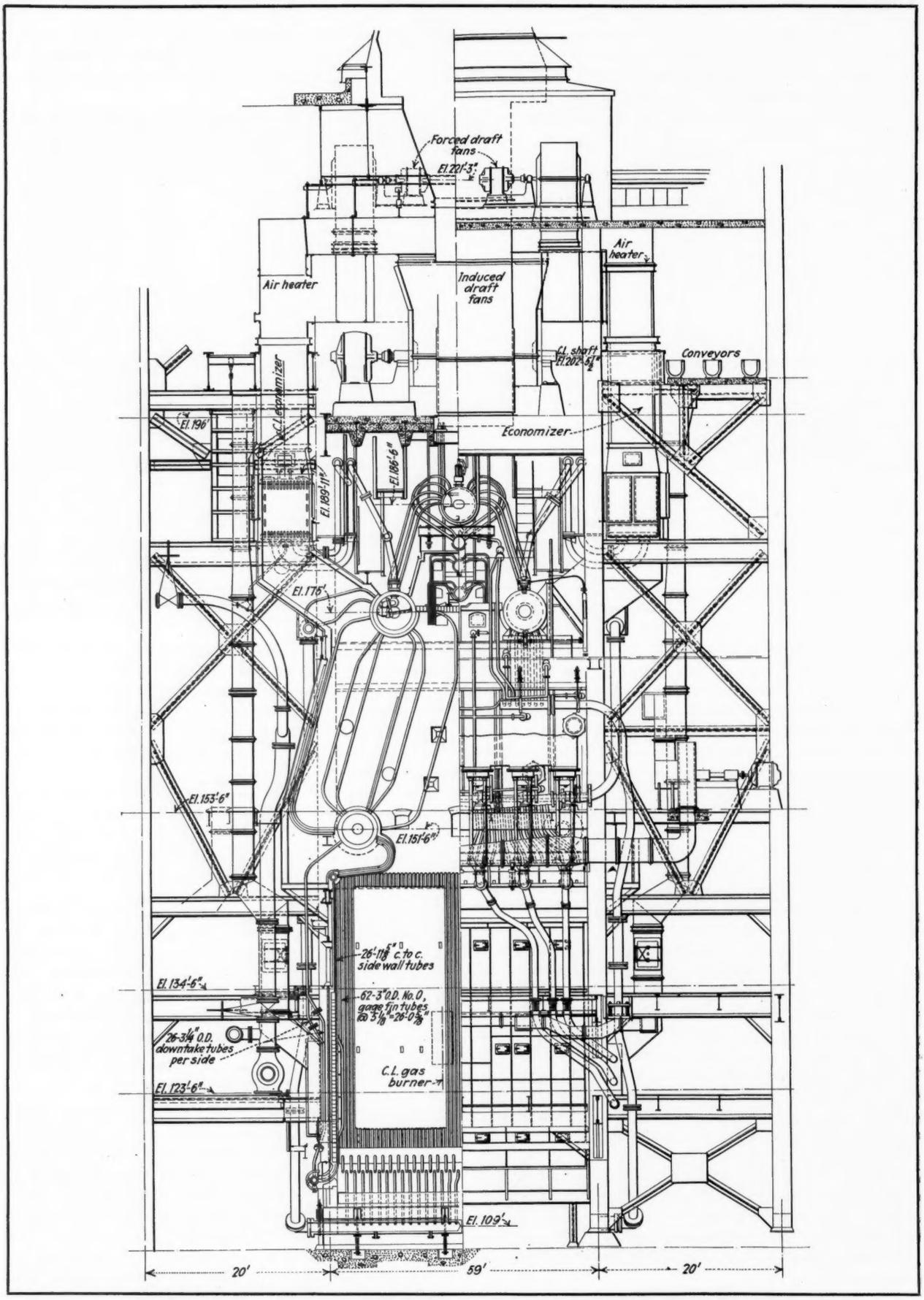
Careful studies were made of the relative economies of gravity and pumped supply, and the latter method was adopted with an arrangement that permits gravity flow at light load or high water and minimum pumping horsepower possible at all other times. The tunnel is 15 ft. inside diameter, 12,000 ft. long, and is some 60 ft. below the surface of the ground.

The pump house is located near the power house and houses four vertical propeller-type pumps, each capable of elevating 157,750 gal. per min. 14.5 ft. and is driven by synchronous motors arranged for two-speed operation, namely, at 138 and 277 r.p.m.

The tunnel was excavated by the shield method, driving through a viscous clay soil. Following the shield, interlocking concrete blocks, ten to a ring, each weighing 3420 lb. were set up to give an outside diameter of 21 ft. This structure was then lined with monolithic concrete to a thickness of 18-in. and when set, the rough spots were smoothed down with emery stone to minimize the friction.

Operation

The unit was started and brought up to speed July 16, which was accomplished without any vibration or rubbing or any trouble with the boiler or accessory equipment. Steam was supplied at 600 lb. pressure, 600 deg. fahr. temperature, using the gas-fired facilities of the boiler and the booster feedwater pumps. When the unit reached full speed a vacuum of 1 in. absolute was obtained on the condenser, showing that the entire piping system was very tight, after which the unit was shut



Sectional elevation through steam plant showing one of high pressure steam generating units.

down for permanent electrical connection and boiler inspection.

The unit was again started on July 23 and brought up to speed without any rubbing or vibration. Steam was supplied at 600 lb. pressure and 600 deg. fahr., using the gas-fired facilities of the boiler and the booster feedwater pumps. Steam was put on the steam reheaters while the unit was warming up. The initial load of 5,000 kw. was placed on the unit and the initial steam temperature gradually raised to 725 deg. fahr. and the reheat temperature to 450 deg. fahr.

The unit was operated in this manner for several hours and then powdered coal was introduced, the pressure raised to 900 lb., and the load gradually increased to 15,000 kw. The main feedwater pumps were then placed in service, but no difficulty was experienced except that it was necessary gradually to bring the steam pumps up to speed and watch the shaft packing. The motor-driven feed pumps were started at short intervals and packing adjustment made, and when the packing became set the pumps ran continuously at full pressure.

The feedwater heaters were cut in one at a time and a few minor air leaks corrected. The low-pressure heater was not used due to an air leak which could not be corrected in the short time the unit was in operation. The steam pressure was raised to 1200 lb. and the load gradually increased to 33,000 kw. and held for about 4 hr., permitting minor adjustments on boiler-control equipment. No steam leaks developed in the high-pressure steam lines. In the small low-pressure lines several leaks developed due to flanges or unions not being drawn up tightly. The load was limited to 33,000 kw. due to incomplete electrical switchboard connections.

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Discussion

By HENRY KREISINGER

Combustion Engineering Corporation, New York

The high pressure steam generating equipment consists of two units each having a capacity of 700,000 lb. of steam per hr. from feedwater temperature at 425 deg. fahr. to steam at 1350 lb. pressure and 750 deg. total temperature. These units occupy the same space in the boiler room that was formerly occupied by two 250 lb. pressure units each having a capacity of 250,000 lb. of steam per hr.

One of these units is shown on page 22. From the standpoint of arrangement, the unit can be considered to consist of two opposed units each having one boiler with separate water circulation and water supply, one superheater, one economizer and one air preheater set over a single water-cooled furnace and forming one complete unit. The entire unit is about 110 ft. high and occupies a floor space approximately 30 by 42 ft.

The boiler part of the complete unit consists of two nests of bent tubes expanded into two pairs of drums. Each unit, therefore, has two water drums and two steam drums. In addition there is a centrally located dry drum set about 15 ft. above the center of the steam drums.

All drums are forged seamless steel. The two lower drums are 40 in. i. d. and 31 ft. 9 in. overall length. The two steam drums are 44 in. i. d. and 36 ft. long. The dry drum is 40 in. i. d. and 26 ft. long between the insides of the heads. The tubes, 1752 in number, are all 3 in. o. d. and of number 0 gage thickness.

The superheaters are of the inter-tube type and are placed among the tubes of the first banks next to the furnace. They are made of 2 in. o.d. tubes and have a total heating surface of 11,500 sq. ft. per complete unit.

The economizers are of the fin-tube type and are placed above the gas outlets from the boiler. They are made of 2 in. o.d. tube number 2 gage thickness. The tubes are placed horizontally across the path of gases and arranged in 18 staggered rows, 14 tubes in a row. The top and bottom rows are expanded into forged steel inlet and outlet headers. The intermediate rows are equipped with return bends. The fins are ¼ in. thick by 2 in. wide, welded to the top and bottom of the tubes. The effective length of the tubes is 24 ft.

The air preheaters are of the plate type and are located above the economizers. The air passages are ⅝ of an in. and the gas passage ¾ of an in. wide. The length of the air preheaters is 18 ft. and the width, 5 ft.

The furnace is completely water cooled. The walls are made of 3 in. o. d. tubes with fins $\frac{5}{16}$ in. thick and 1 in. wide. The arches also are made of fin tubes. The bottom of the furnace is protected by a row of 3 in. tubes forming a water screen.

The total heating surface of the furnace exposed to radiant heat is 5234 sq. ft.

The furnace is fired with pulverized coal by the tangential method. There are three burners in each corner near the bottom of the furnace. The burners direct the mixture of coal and air tangent to a circle about 8 ft. in diameter in the center of the furnace.

The coal is supplied to the burners by 12 feeders, 6 under each of the two old pulverized coal bunkers located on the two sides of the unit.

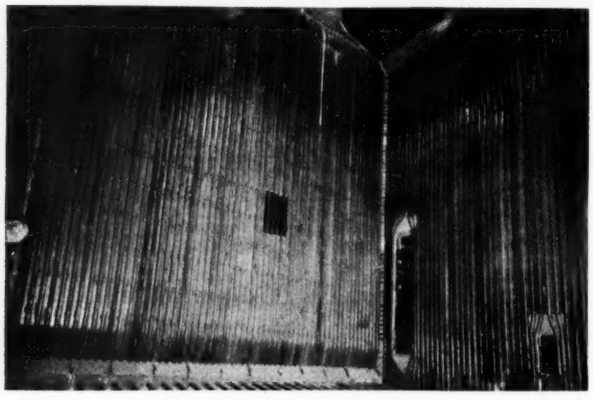
Blast furnace gas can be burned up to 50,000 lb. of steam per unit, and it is used to bring the unit up to working pressure and warming up the turbine. Coal is the principal fuel during full load operation.

The furnace is 25 ft. 8 in. by 27 ft. in cross section and 30 ft. high between the water screen and the arches. The total height between the water screen and the apex at the top of the furnace is 52 ft. The total available combustion space is 25,500

cu. ft. When the unit is operated at its maximum capacity of 700,000 lb. of steam per hr., the average rate of heat liberation is 31,000 B.t.u. per cu. ft. per hr. To operate the unit at its full rating 53,900 lb. of coal of 14,300 B.t.u. heat value is burned per hr.

The ash is removed from the bottom of the furnace by two cast iron conveyors and dropped into two crushers from which it is conveyed by a pneumatic system into a car loading bin.

There are four forced draft fans supplying air through the air preheaters to the burners. Their



Interior of furnace of high pressure unit.

combined capacity is 200,000 c.f.m. at 100 deg. fahr. and 10¼ in. of static pressure. The fans are of the turbo-vane type with double width and double inlet. Each fan is driven by one 2-speed motor—150 and 60 hp. at 1200 and 900 r.p.m. respectively. The motors are of the induction type, 3 phase, 60 cycle and 2300 volts. Regulation of the air volume flowing through the fan is obtained by means of dampers placed in the passage of the fan.

There are two induced draft fans per unit having a total capacity of 420,000 c.f.m. at a temperature of 400 deg. fahr. and a static pressure of 12½ in. The fans are of the steel-plate type, double width and double inlet. Each fan is driven by one 2-speed induction motor of 800 and 500 hp. at 514 and 400 r.p.m. speed respectively. The power supply is 3 phase, 60 cycle and 2300 volts. Regulation of gas flow is obtained by means of dampers placed in the inlet duct to the fans.

The induced draft fans and motors with their two speeds were selected to obtain economic operation at different ratings. When rating of 700,000 lb. of steam per hr. is desired, the two fans are operated at the higher speed with the regulating dampers nearly open. When these fans are operated at their lower speed, an output of 600,000 lb. of steam per hr. can be obtained. Lower ratings are obtained by the damper regulation. In case of failure of one induced draft fan, the other fan when operated at its higher speed will give a rating of 500,000 lb. of steam per hr. The forced draft fans can be operated in a somewhat similar manner. With all four fans operating at the higher speed, enough air can be delivered to the furnace to generate 700,000 lb. of steam per hr. With the four forced draft fans operating at the lower speed, a rating of 600,000 lb. of steam per hr. can be obtained. Two fans operating at the higher speed will deliver a sufficient volume of air to the furnace to generate 500,000 lb. of steam per hr.

The unit has been designed to generate 500,000 lb. of steam with 87 per cent efficiency, 650,000 lb. of steam with 86 per cent, and 700,000 lb. with 85.5 per cent efficiency.

The furnace heating surfaces generate 35 to 40 per cent of the total steam output.

Table 1 gives the principal dimensions of the steam generating units.

TABLE I

PRINCIPAL DIMENSIONS OF THE STEAM GENERATING UNITS

Boiler	
Number of drums per unit	5 ft.
Inside diameter of the two lower drums	40 in.
Thickness of walls of the lower two drums	5¼ in.
Length overall—lower two drums	31 ft. 9 in.
Inside diameter of the two steam drums	44 in.
Thickness of walls of steam drums	5¼ in.
Length overall—steam drums	36 ft.
Inside diameter of dry drum	40 in.
Thickness of dry drum	3 in.
Length overall—dry drum	26 ft.
Number of boiler tubes per unit	1752
Outside diameter of boiler tubes	3 in.
Thickness of boiler tubes	0 gage
Total heating surface of boiler	32,040 sq. ft.
Superheater	
Number of superheaters per unit	2
Size of tubes	2 in.
Heating surface of each superheater	5,737.5 sq. ft.
Total superheating surface per unit	11,475 sq. ft.
Economizer	
Number of economizers per unit	2
Type of economizer	Fin tube
Number of rows of tubes in each economizer	18
Number of tubes in each row	14
Size of tubes	2 in. o.d.
Thickness of tubes	No. 2 gage
Size of fins	¼ in. thick by 2 in. wide
Effective length of tubes	24 feet
Heating surface of each economizer	7,000 sq. ft.
Total economizer surface per unit	14,000 sq. ft.
Air Preheater	
Number of air preheaters per unit	2
Type of air preheater	Plate
Width of air spaces	⅝ in.
Width of gas spaces	¾ in.
Length of elements	18 feet
Width of elements	5 feet
Number of elements in each air preheater	180
Heating surface of each preheater	32,400 sq. ft.
Total air heating surface per unit	64,800 sq. ft.
Furnace	
Type of furnace	Fin tube, completely water cooled
Size of tubes	3 in. o.d.
Thickness of tubes	11/32 in.
Size of fins	5/16 in. thick 1 in. wide
Spacing of tubes in walls	5⅛ in. between centers
Size of water screen tubes	3 in. o.d.
Spacing of water screen tubes in each row	10¼ in.
Total heating surface of furnace exposed to radiation	5,234 sq. ft.
Inside dimensions of furnace	26 ft. 11⅛ in. by 25 ft. 8¼ in.
Height of furnace—water screen to arches	30 ft.
Height of furnace—water screen to apex of furnace	52 ft.
Effective combustion space	25,480 cu. ft.
Kind of fuel	Powdered coal and blast furnace gas
Method of firing pulverized coal	Tangential
Method of blast furnace firing	Opposed
Number of coal burners	3 in each corner—12 in all
Number of blast furnace burners	2 one in each of two opposing walls
Heating Surface	
Total water evaporating surface	37,274 sq. ft.
Total water heating (economizer) surface	14,000 sq. ft.
Total superheating surface	11,475 sq. ft.
Total air preheating surface	64,800 sq. ft.
Total heating surface of all kinds	127,549 sq. ft.

Combustion Calculations from Gas Analyses

By EDWARD C. MATHIS
Stitzer and Waddell
Toledo, Ohio

The author discusses the various combustion calculations that can be made from gas analyses and offers an example based on by-product, coke-oven gas which is fairly typical of other common commercial fuel gases. A discussion of these calculations was also included in Mr. DeBaufre's article on typical gaseous fuels in December, 1931, COMBUSTION but the present article presents the matter in a somewhat different style and the example is worked out on a volume basis rather than a weight basis as used in Mr. DeBaufre's article.

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FROM the analyses of fuel gases, it is possible to make the following calculations:

Air required for combustion.

Volume of combustion products and volume of each component thereof.

Per cent of carbon dioxide in the combustion products.

Dewpoint of the combustion products.

Heating value of the fuel gas.

Specific gravity of the fuel gas.

The best manner of clearly explaining the processes of calculation of the various functions is by the use of an example and the best type of a gas analysis for this purpose is that of the usual by-product coke oven gas in which are found all the constituents which occur in the other common commercial fuel gases.

Component Gas	*Symbol*	*Per cent by volume*
Carbon dioxide	CO_2	1.7
Illuminants	Ill.	3.0
Oxygen	O_2	0.1
Carbon monoxide	CO	5.5
Hydrogen	H_2	53.0
Methane	CH_4	32.8
Ethane	C_2H_6	1.0
Nitrogen	N_2	2.9
		100.0

More recently other fuel gases are entering the field in commercial quantities, such as refinery still gases and liquefied petroleum gases, and these introduce additional component gases of the hydrocarbon series such as propane, butane, ethylene and propylene. These will be excepted in this text.

Due to inherent characteristics of the analytical procedure, results are obtained directly on a dry basis and are reported as the example above. No water vapor is included. Of course, all manufactured gases come into contact with water during the course of the production or storage and thereby reach a degree of saturation dependent upon incidental temperature and pressure. In underground transmission lines, the gas is cooled to, and is usually saturated at, ground temperatures of probably 45 to 60 deg. fahr. The volume percentage of water vapor under these conditions may be obtained by dividing the pressure of saturated aqueous vapor, which may be obtained from reference tables, by the absolute pressure on the gas. Gas saturated at 55 deg. fahr. and atmospheric pressure carries 1.45 per cent water vapor. Correction for this amount of inert matter must be applied for precise volume measurements. If the gas is suspected of being unsaturated, the degree of saturation must be determined by means of a hygrometer such as the wet and dry bulb method.

The component called "Illuminants" is a group of gases composed of small amounts of several unsaturated aliphatic hydrocarbons such as ethylene, propylene, butylene and sometimes benzene. They are determined readily as a group in the course of ordinary analysis, but determination of each one separately involves a difficult and highly specialized procedure. In making calculations they are also dealt with as a group and the accuracy of the constants, which must be approximated for the group, is more or less uncertain. Fortunately the quantity of illuminants appearing in the common gases is low, reaching the greatest magnitude in carburetted water gas, wherein it rarely exceeds 11

per cent. The approximated constants appear in Table I.

Volume of Air Required and Combustion Products

Combustion calculations will be simplified for the practical man if he considers the reported analysis to represent the quantities of each component as a fractional part of a cubic foot, the sum of which makes up one cubic foot of gas. The analysis reported in per cent is converted to a cubic foot basis by dividing the percentage of each component by 100, which is tantamount to moving the decimal point two places to the left. This has been done in the second column of Table I.

TABLE I

Gas	Cu. ft. of components in 1 cu. ft. gas	Cu. ft. oxygen to burn 1 cu. ft. each component.	Cu. ft. oxygen required by the gas	Cu. ft. CO_2 formed per cu. ft. component	CO_2 formed from the gas	Cu. ft. water vapor formed per cu. ft. of component	Cu. ft. water vapor formed from gas.	Nitrogen
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
CO_2	.017	....	....	×1.0	.017	....	....	....
*Ill.	.030	×3.5	.105	×2.35	.070	×2.35	.070	....
O_2	....	....	....	....	....	....	....	....
CO	.055	×0.5	.0275	×1.0	.055	....	....	....
H_2	.530	×0.5	.265	....	....	×1.0	.530	....
CH_4	.328	×2.0	.656	×1.0	.328	×2.0	.656	....
C_2H_6	.010	×3.5	.035	×2.0	.020	×3.0	.030	....
N_2	.029	....	....	....	....	....	....	.029
Total	1.000		1.0885		.490		1.286	
Less oxygen in gas			.001					
Oxygen req. from air			1.0875					

Air req. $= \frac{1.0875}{.209} = 5.2033$

Nitrogen from air $5.2033 - 1.0875 = \frac{4.116}{4.145}$

* Note: Formula assigned to illuminants from coke oven gas $C_{2.38}H_{4.70}$. From carburetted water gas $C_{2.54}H_{5.08}$; oxygen required per cu. ft.—3.80 cu. ft.; CO_2 and H_2O formed per cu. ft.—2.54 cu. ft.

The third column of Table I gives the cubic feet of oxygen required to perfectly react with one cubic foot of the component which, multiplied by the fractional part of a cubic foot of each component yields in column four the oxygen required by that component. The sum of this column is the total quantity of oxygen which must be furnished to exactly unite with one cubic foot of the integral gas. Of this requirement .001 cu. ft. happens to be supplied in the fuel gas itself and is deducted from the total required to determine the quantity which must be furnished from the air. Air is made up of 20.9 per cent oxygen and 79.1 per cent nitrogen (and a small quantity of other inert gases). The air necessary to furnish the proper amount of oxygen is found by dividing the oxygen by .209. The accompanying nitrogen passes through the flame and becomes part of the combustion products.

Column 5 gives the cubic feet of carbon dioxide, and column 7 the cubic feet of water vapor formed by the combustion of one cubic foot of the component. These values multiplied by the fractional cubic foot of its respective component give the volumes of CO_2 (column 6) and H_2O (column 8) from each component. The summation of each column is the quantity of CO_2 and H_2O vapor from one cubic foot of the fuel gas mixture. Nitrogen in the gas passes into the combustion products unchanged.

Bringing the results of Table I together:

Oxygen required per cu. ft. gas	1.0875 cu. ft.
Air required per cu. ft. gas	5.2033 cu. ft.
Combustion products per cu. ft. gas—	
CO_2	.490 cu. ft.
H_2O	1.286 cu. ft.
N_2	4.145 cu. ft.
Total	5.921 cu. ft.

Dewpoint of Flue Gas

Under the conditions of temperature and pressure incidental to the phases being considered here, it is sufficient for most industrial purposes to assume that all the gases involved adhere perfectly to ideal gas laws. Stating it another way, the fuel gas and the combustion products retain the same volumetric relations and percentage composition whether at 60 deg. or 150 deg. fahr., atmospheric pressure or one pound gage. Of course the composition of the combustion products as reported above can only exist in fact above the temperature at which the water vapor begins to condense. Below this temperature, called the dewpoint, the percentage composition as given can exist only as a hypothetical case.

Moisture vapor condensing to liquid water in the stacks of a furnace absorbs the sulphur oxides produced by combustion of sulphur compounds, and becomes a solution of sulphuric acid which causes the rapid corrosion of metal connections. The matter of dewpoint then becomes one of consequence and it is possible to estimate this value.

The quantity of water vapor present in a gaseous mixture is the ratio between its vapor pressure and the total or absolute pressure on the mixture. This relation is expressed graphically in the curve, Fig. 1, for the conditions of saturated water vapor between 50 and 170 deg. fahr., and at atmospheric pressure. In the combustion products of the specific case above, there is $\frac{1.286 \times 100}{5.921} = 21.7$ per cent water vapor. Referring to Fig. 1, it is found that a volume saturated with water vapor equivalent to 21.7 per cent of that volume at atmospheric pressure has a dewpoint of 144 deg. fahr. To repeat in other words, the water vapor in the combustion products of the example gas when perfectly burned will begin to condense when the temperature of the products falls to 144 deg. fahr.

If there is surplus air supplied for combustion, the dewpoint will be lower. Suppose that 25 per cent more air than is needed for perfect combustion is furnished:

$5.2033 \times .25 = 1.301$ cu. ft. excess air.

1.301 cu. ft. air is composed of .272 cu. ft. of oxygen

and 1.029 cu. ft. of nitrogen. These gases are not needed for combustion and become a part of the combustion products.

CO_2	.490 cu. ft.	
H_2O	1.286 cu. ft.	
O_2	.272 cu. ft.	
N_2	5.174 cu. ft.	(4.145 1.029)
	7.222 cu. ft.	

The water vapor then represents $\frac{1.286 \times 100}{7.222} =$ 17.8 per cent. From the curve it is found that the dewpoint temperature now is 136 deg. fahr.

Ultimate CO_2

The per cent of CO_2 found in the combustion products is a criterion of the completeness of combustion. The value which would be obtained by proper Orsat analysis, called "ultimate CO_2", may be predicted from the analysis. The composition of the flue products as given previously is:

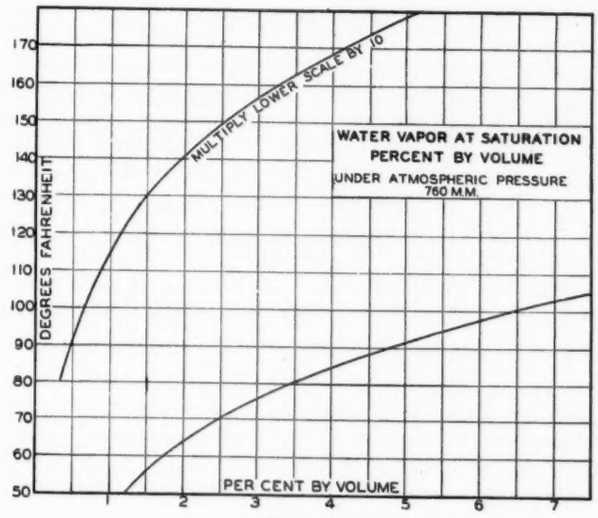

Figure 1.

CO_2	.490 cu. ft.	
H_2O	1.286 cu. ft.	
N_2	4.145 cu. ft.	
	5.921 cu. ft.	

By the time the sample has reached the Orsat burette, the moisture has condensed out because it is far below the dewpoint. The composition of the gas then would be:

CO_2	.490 cu. ft.	=	10.6 per cent
N_2	4.145 cu. ft.	=	89.4 per cent
	4.635 cu. ft.	=	100.0 per cent

10.6 per cent CO_2 obtained by analysis is indicative of perfect combustion of the gas.

If the flame is 25 per cent over-ventilated, the composition of the combustion products becomes:

CO_2	.490 cu. ft.	=	8.2 per cent
O_2	.272 cu. ft.	=	4.6 per cent
N_2	5.174 cu. ft.	=	87.2 per cent
	5.936 cu. ft.	=	100.0 per cent

The per cent of excess air may be calculated from the flue gas analysis; using the above figures:

$$\frac{4.6 \times 3.78}{87.2 - (4.6 \times 3.78)} = 25 \text{ per cent excess air,}$$

where 3.78 is the factor for volumes of nitrogen per volume of oxygen in air.

Heating Value in B.t.u. Per Cubic Foot

Calculation of heating value per cubic foot from the analysis simply involves multiplication of each component fraction by its heating value per cubic foot.

	Cu. ft. of component in 1 cu. ft. gas	Gross B.t.u. per cu. ft. of component at 60 deg. fahr. 30 in. mercury, dry	B.t.u. furnished by component fraction
CO_2	.017	.....	....
Ill.	.030	×1850	55
O_2	.001	.....	....
CO	.055	× 323	18
H_2	.530	× 326	173
CH_4	.328	×1009	331
C_2H_6	.010	×1764	18
N_2	.029	.....	....
Total	1.000		595 B.t.u. per cu. ft.

595 B.t.u. is the gross heating value of one cubic foot of the fuel gas at 60 deg. fahr., 30 in. mercury column pressure and dry.

The heating values per cubic foot of the component gases are subject to dispute. The value selected for illuminants is that reported by the U. S. Bureau of Mines, Pittsburgh Experiment Station[1]. From the same source and another[2], a value of 2,000 B.t.u. per cu. ft. has been chosen for the illuminants from carburetted water gas. Since a change in any one of the numerous conditions involved in the manufacture of both of these gases, especially carburetted water gas, may cause a change in the nature of the illuminants, it is evident that these arbitrary heating values will not be suitable for all cases. However, until better knowledge is obtained they may be used without appreciable error for general purposes.

The heating values of the other component gases, while infinitely better defined, are not universally constant. The author has shown elsewhere[3] the variations in values reported by different authorities. Those used here were prepared by the United Gas Improvement Company and were chosen because they seem to have come into more general use among gas technologists than any of the others.

The heating value of 595 B.t.u. obtained above is termed the gross heating value. Net heating value is somewhat less than this.

In the process of combustion, water vapor is formed which absorbs from the reaction latent heat of vaporization. This heat is liberated again but not until the water vapor condenses to liquid water. It was found previously that water vapor in the products of combustion does not begin to condense until a temperature of 144 deg. fahr. is reached. In

[1] Frey and Yant, Industrial and Engineering Chemistry, Vol. 19, p. 1358 (1927).
[2] J. R. Branham, American Gas Journal, August 1931, page 42.
[3] E. C. Mathis, Gas Age-Record, Vol. 68, p. 749 (Nov. 21, 1931).

most industrial operations this temperature is encountered well along in the stack system and the latent heat is lost to the operation. The net heating value then is the gross heating value less the latent heat of the water vapor present in the combustion products. Gross heating value is obtained directly from the gas calorimeter and is more commonly reported than net heating value.

The heat correction per hypothetical cubic foot of water vapor at 60 deg. fahr. and 30 in. mercury is 53 B.t.u. It was found that in the combustion products of our example gas there were 1.286 cu. ft. water vapor. $1.286 \times 53 = 68$ B.t.u. $595 - 68 = 527$ B.t.u. per cu. ft. which is the net heating value of the example gas.

Specific Gravity

Still considering the analysis as representative of a cubic foot, the specific gravity of the fuel gas may be calculated by multiplying the specific gravity of each of the components by its fractional part of a cubic foot and summing up.

CO_2	.017	× 1.529	=	.026
Ill.	.030	× 1.10	=	.033
O_2	.001	× 1.105	=	.001
CO	.055	× .967	=	.053
H_2	.530	× .069	=	.037
CH_4	.328	× .553	=	.181
C_2H_6	.010	× 1.037	=	.010
N_2	.029	× .970	=	.028
				.369

The specific gravity of the example gas referred to air is .369. In other words the gas is .369 as heavy as air. One cubic foot of air at 60 deg. fahr., 30 in. mercury and dry weighs .07658 lb. The gas then weighs .07658 × .369 or .02826 lb. per cu. ft.

There are other data which may be calculated from the analysis such as theoretical flame temperature and potential heat carried away by combustion products, but these functions involve lengthy discussion and have been handled in a scholarly manner elsewhere in this magazine.[4]

[4] Wm. L. DeBaufre, Combustion, Dec. 1931.

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Edison Medal Awarded To E. W. Rice, Jr.

To Edwin W. Rice, Jr., conspicuous pioneer and one of the founders of the General Electric Co., has been awarded the Edison medal of the American Institute of Electrical Engineers for 1931. The citation accompanying the award reads: "for his contributions to the development of electrical systems and apparatus and his encouragement of scientific research in industry." The presentation of the medal to Mr. Rice will take place in New York on January 27.

Paul S. Clapp Resigns As Managing Director Of N. E. L. A.

Paul S. Clapp resigned in December as Managing Director of the National Electric Light Association to accept election as Vice-President of the Columbia Gas and Electric Corporation.

His successor has not been appointed up to the time of going to press.

Mr. Clapp succeeded M. H. Aylesworth as Managing Director of the N. E. L. A. in October, 1926. During his five-year term of office, he gained particular recognition for his work in promoting the program for the commercial development of the companies comprising the association.

During the World War Mr. Clapp served as Captain in the United States Army Signal Corps. From December, 1918, to February, 1919, he was associated with the Peace Commission in Paris as a member of the Committee for the determination of damage in allied countries. Subsequently he established and supervised the telephone and telegraph service between the various capitals of Europe, by which the relief work was administered.

Prior to his connection with the N. E. L. A. Mr. Clapp was special assistant to the Secretary of Commerce. He was born in Iowa and graduated from Iowa State College at Ames as electrical engineer. His home is in New York City.

Death of Howard R. Sargeant, engineer of the commercial division of the Merchandise Department of the General Electric Company, Bridgeport, Conn., occurred December 8 following an attack of appendicitis. Mr. Sargent was a graduate of M. I. T. class of 1893, entering the service of the old Thomson-Houston Company at Lynn, Mass., was transferred to Schenectady in 1894 where he remained until the organization of the Merchandise Department of the company in 1922. Mr. Sargent was then transferred to Bridgeport where in 1926 he was made engineer of the Merchandise Department.

Northern Equipment Co., Erie, Pa., announces the appointment of G. L. Simonds, Winter Haven, Fla., as representative in the State of Florida for Copes Feed Water Regulators, Differential Pressure Control Valves, Pump Governors, Condensate Drainage Controls and allied Equipment.

Whiting Corporation, Harvey, Illinois, through its subsidiary, the Grindle Fuel Equipment Co., has announced the appointment of Mr. C. F. Herington as sales engineer. Mr. Herington has had 28 years' experience in engineering work, selling and erection of pulverized coal plants, in the United States, Canada, Africa and Belgium. Mr Herington also is author of an authoritative book on powdered coal, "Powdered Coal as a Fuel" of which the second edition has been revised and enlarged.

Trend in Design of Principal Mechanical Equipment of Steam Stations*

By D. C. HORMELL
Assistant Mechanical Engineer
Byllesby Engineering
and Management Corporation

This is an excellent review of the trend of design of the principal equipment used in steam stations. The author discusses turbines, condensers, bleeder heaters, boilers, feedwater, superheaters, reheaters, economizers, air preheaters, furnaces, fuel burning and auxiliaries . . . . All the developments and changes discussed, which have taken a permanent place in design, have either directly or indirectly reduced the ultimate cost of generating electrical energy. The extent of achievement in this direction is indicated by recent statistics issued by the National Electric Light Association which show that the cost of steam generating stations has decreased 12 per cent during the past eight years.

A GREAT many changes have taken place during the past ten years in the design of steam power plant equipment, the trend being a distinct effort to better the economic set-up. The rate of development is always a function of demand, which in turn is a function of the economic condition of the country as a whole.

In order that we may show the economic trend in the design of mechanical equipment for steam stations, it will be necessary to analyze the principal component parts. Economies have been effected in the past ten years that have served to firmly entrench the public utility as a manufacturer and distributor. If we are to maintain our present position, it is not only essential but imperative that we continue to manufacture and sell our product cheaper than the individual unit can supply it. Although this problem is ever an important one, in these days of close competition and political agitation it would appear to have even added significance.

Much has been said and considerable written about low B.t.u.-per-kilowatt stations, without due regard for the economics of the particular problem. In these days of extensive research and cooperation on the part of the manufacturer, it is possible to build stations for heat rates of 10,000 to 20,000 B.t.u. per kilowatt, and it is the engineer's job to make the proper selection. As to the correct rate for a given project, this can be determined only by close study and analysis of the factors affecting the particular problem.

In order that we may continue to maintain our position in the industrial world, it is fitting at this time to take an account of stock, so to speak. Based on information collected and analyzed by the N. E. L. A., the first cost of generating stations from 1922 to 1929 has been reduced approximately 12 per cent.

In order that we may show the economic trend in the design of mechanical equipment of steam stations, it will be necessary to study the individual classes of equipment which make up a successful modern plant. We must concern ourselves not alone with design but dollar efficiency as applied to first cost and operating cost. All equipment entering into a plant is important and must be selected not only with full regard to its own limits, but to its effect on the whole.

Ten years ago, it was not considered bad operation to develop a kilowatt-hour on 2½ pounds of coal, or approximately 35,000 B.t.u., in our better central stations. The average coal rate per kilowatt for central stations was three pounds. Today, we have central stations that develop a kilowatt on less than one pound of coal—12,500 B.t.u. or 10,000 B.t.u. if we wish to consider the mercury turbine in this set-up.

The average coal rate of central stations for the year 1929 was 1.7 pounds per kilowatt.

* Presented at the 1931 convention of the engineering department, Byllesby Engineering and Management Corporation.

The natural question is: What changes have taken place during this period to produce these economies? Why were they not effected sooner, and why are improvements being made now at a set rate?

I shall answer by considering in turn each of the principal kinds of mechanical equipment.

Steam boilers for converting the heat in the fuel to a form usable by the steam turbine.

Superheaters to add more heat to the steam after leaving the boiler.

Turbo generators for converting the heat in the steam to electrical energy.

Condensers, the chief aid to the turbo generator, increasing the efficiency of the turbine by reducing the back pressure against which it must exhaust.

Bleeder heaters, heat exchangers for preheating the boiler feedwater on its way to the boiler by means of steam extracted from the main turbine.

Economizers, heat exchangers to further heat the feedwater on its way to the boiler by heat extracted from the flue gases after leaving the boiler.

Air preheaters, heat exchangers for heating the air for combustion by absorbing heat from the flue gases after leaving the economizer.

Water cooled furnaces, boxes in which the heat in the fuel is liberated.

Fuel burning equipment, mechanism for conveying fuel to the furnace and mixing with air for efficient combustion.

Turbines: The development of the reciprocating

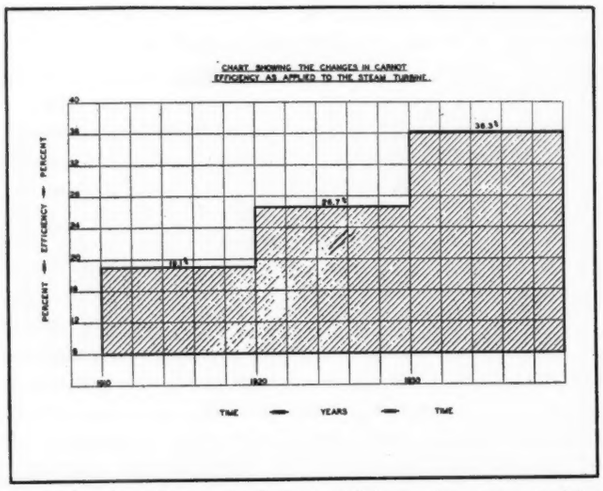

Chart showing change in Carnot efficiency for steam turbines with respect to time.

engine covered at least ninety years. The development of the steam turbine has taken place within a period of about thirty years. The true reason for this more rapid development is not the high technical skill and scientific progress of the present age, but rather that metallurgical and manufacturing arts were available to the turbine manufacturer which were not available to the early manufacturer of steam engines.

The steam turbine is generally looked upon as of European origin, the reduction to useful practice having been made by Messrs. Parsons and De Laval, but steam turbines were commercially built in Syracuse, New York, as early as 1833 and applied to saw mill practice. No serious attempts were made toward further development of steam turbines in this country until the Westinghouse Company secured the rights to manufacture them under a license from Sir Charles A. Parsons.

In 1896, a 120 kilowatt condensing turbine was built in Pittsburgh and drove a direct current generator at 5000 r.p.m. This machine had a water rate of 25.6 pounds per kilowatt-hour when operating with 160 pounds steam pressure and 27.1 inches vacuum. From the standpoint of the turbine, the installation was a success.

In 1899, a 400 kilowatt turbine for the following conditions was built:

150 Pounds
100 deg. fahr. Superheat.
28 Inches Vacuum

A water rate of 17.0 pounds per kilowatt at the best loading was obtained.

The first central station installation of a steam turbine came in 1900 by the Westinghouse Company at the plant of the Hartford Electric Company, Hartford, Connecticut. This machine had a capacity of 2000 kilowatts and operated at 1200 r.p.m. The turbine was at least twice as large as any machine that ever had been built. It aroused such general interest that the General Electric Company entered the field and, shortly thereafter, commenced the construction of 5000 kilowatt vertical units for the Commonwealth Edison Company of Chicago.

The rapid strides made in central station practice in this country have brought about development of turbines for land practice in sizes that have gone beyond any European practice. There is an impression that the development of the steam turbine in this country from 1900 has grown from a very poor, uneconomical machine to our present designs. Generally speaking, this is not true, for it may be seen from a comparison of the steam consumption of the earliest machines and our present day designs that they compare quite closely.

It is true that improvements have been made in producing less expensive, more reliable, and more economical turbines. Improvements in station economy, however, have been due to the application of increased speeds for a given capacity, higher steam pressures, higher temperatures, bleeder feed heating, and improved condensers rather than to any material change of basic thought or principle as regards turbine systems.

There was a time when the steam turbine was considered to be a machine of too high speed for general application. This is no longer true, as the electrical engineer has successfully overcome many of the early difficulties.

The demands of our large systems today for greater capacities from single shaft turbines, resulting in the turbine manufacturers offering a tandem arrangement of stages, have again put the generator designer at a disadvantage. At the present time, the limit of capacity from a single shaft

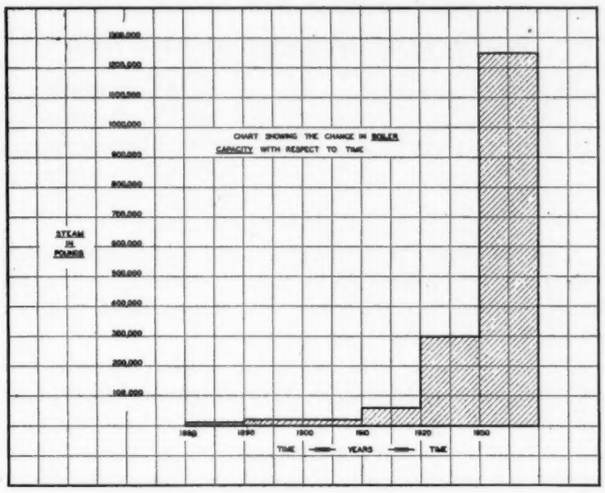

Chart showing change in boiler capacity with respect to time.

machine is set by the capacity that the electrical engineer is able to build in a single generator rather than by the turbine builder's ability to supply primary power.

The sizes of steam turbines have continually increased from 1899 to the present time. The past ten years have seen the capacity of turbo-generators increase from 60,000 kilowatts to 208,000 kilowatts in multi-cylinders. The price paid the manufacturer per kilowatt has tended to increase, but benefit has accrued to the buyer by virtue of a reduction in other items, such as cost of building, foundations, auxiliaries, maintenance and operating labor.

In 1918, there were few turbines operating in this country making use of steam in excess of 300 pounds. Since then, we have covered the pressure range from 300 pounds to 1400 pounds. The rates of development and refinement in the steam tables for pressures in excess of 300 pounds, as well as in boilers and auxiliary steam-making equipment, have in great measure governed the rate of development of the turbine for higher pressures.

Greater Efficiency Effected at Less Cost

Plants are in successful operation today making use of steam at 400, 600 and 1200 pounds. In all cases where the pressure and temperature are increased with respect to the turbine, increased thermal efficiency and reduced coal cost per kilowatt-hour follow.

Where pressures in excess of 450 pounds are used, it becomes desirable to use turbines of either two or three cylinders for complete expansion. Primarily, this is due to inability to design a superheater to supply steam at a temperature in excess of 750 degrees Fahrenheit, or a turbine to operate efficiently on extremely wet steam in the lower stages. Although higher pressures give better economy, multi-cylinder turbines cost more money per kilowatt than single cylinder machines. A well balanced design, however, should more than offset this increase by a reduction in the total cost of power produced.

The trend, in so far as the turbo-generator is concerned, is toward increased size and ouput. Indications are that the steam turbine as a power producer will not be displaced by some new process under development in the immediate future.

It has been demonstrated that the mercury turbine is entirely practical. It must be realized that, to make use of such equipment economically, it must be superimposed on a steam cycle. The application of this cycle, however, is at present limited to development where high initial expense can be justified.

Other binary cycles are being studied, but to date no other practical system has been demonstrated.

The development that has taken place in turbine design during the past ten years has resulted in reduction of ultimate costs, directly or indirectly, greater reliability, more exacting performance, lower maintenance cost and longer life expectancy.

Condensers: The condenser, the equipment used for reducing the pressure at the last stages of the turbine to a point approaching the perfect vacuum and reducing the steam exhausted from the turbine to water, is very important. In fact, though it is sometimes classed as an auxiliary because it is coupled to and works in conjunction with the steam turbine, it is a major piece of equipment. Its performance affects directly the steam rate of the turbine. Though in most cases the turbine and condenser are designed and built by different manufacturers, it is essential that the design be such that the condenser and its auxiliaries will permit the turbine to operate to best advantage.

TABLE OF CARNOT EFFICIENCY

Year	*B.t.u.*	*Carnot Efficiency*
1910	17,900	19.1
1920	12,800	26.7
1930	9,400	36.3

In the past ten years, the condenser has changed from a box into which the maximum number of tubes was crowded, to designs in which the heat transfer per square foot of tube has been materially increased. This has been accomplished by special tube arrangements, steam lanes, shape of condenser shell and baffles. More attention has been paid to steam distribution and air removal than before, as well as reduction of the limits of permissible oxygen contained in the condensate. Studies are made to determine the economical vacuum for a given job, this value seldom being the same for any two jobs, as it depends upon the prime mover, boiler, steam pressure, price of coal, load and capacity factor, temperature and quality of circulating water, and the interest rate on money.

Smaller Condensers Have Resulted

These changes in design and method of evaluating have resulted in condensers smaller in surface

but better fitted for the local conditions. Coal has somewhat decreased but not in direct proportion to the surface. The principal benefit has been better performance with respect to time, and lower operating and maintenance costs.

Bleeder Heaters: Thanks to Mr. Insull's foresight in having guaranteed the right to make use of this principle by subscribing to the Ferranti patents, bleeder heaters, sometimes called extraction heaters, are now in general use. They are feedwater heaters which make use of steam extracted from the turbine shell after it has done work in passing through a number of stages in the turbine. These heaters are usually indirect—that is, tubular boxes with a heating medium, extracted steam, on the outside of the tubes and the feedwater on the inside.

The trend during the past ten years has been to increase the number of stages of heating used. Theoretically, it is possible to have as many stages as there are stages in the turbine. To make use of the maximum number of stages is neither practical nor economical. It is now common practice to make use of but three stages of bleed heating. A fourth stage has been used, but its justification from an economic standpoint is questionable in most cases.

Some designers have felt that all feed heating should be done from the boiler room side, making use of a very large economizer section of boiler rather than extraction heaters, while others leaned to a high boiler coupled with an air preheater, doing all of the feed heating by means of extraction heaters. The most economical designs do a certain amount of feed heating on both the boiler room and the engine room side.

The trend today is to make use of both extraction heaters and economizers, recovering lower level heat in each location to the extent that the economies justify. The introduction of extraction heaters into our heat cycles requires an outlay of capital for this equipment. The justification is in a lower station heat rate with a decrease in the capital expenditure, due to a reduction in the cost of boiler and condenser.

Boilers: In general, no class of equipment has been neglected and even abused to the extent that boilers have been. It is only within the last ten years that the average executive has begun to realize that, once a plant is designed and built, the major saving or loss is the result of good or bad boiler performance. Boilers and boiler equipment are bought today only after a very thorough study of all relevant conditions. Most jobs require that boiler equipment be especially designed to meet the existing local conditions. The new procedure is possible because the manufacturer can afford to develop special designs since, due to the size of the equipment, the development represents a smaller percentage of the total cost.

Boilers have increased greatly in size during the last ten years although the increase has not been directly proportional to the increase in steam output. The following table is an indication of the change in boiler capacity with respect to time:

Pounds of Water Evaporated Per Hour	
1880	10,000 Pounds
1890	20,000 Pounds
1910	60,000 Pounds
1920	300,000 Pounds
1930	1,250,000 Pounds

The increase in steam capacity has been accompanied by increases in steam pressure and temperature, more efficient use of steam and reduced steam consumption per kilowatt.

Water temperature within a boiler operating at 200 pounds pressure is 388 degrees Fahrenheit, and the exit gas temperature is about 500 degrees Fahrenheit. If the same boiler were built for an operating pressure of 1200 pounds, the temperature of the water within the boiler would be 580 degrees Fahrenheit, while the exit temperature of the gases

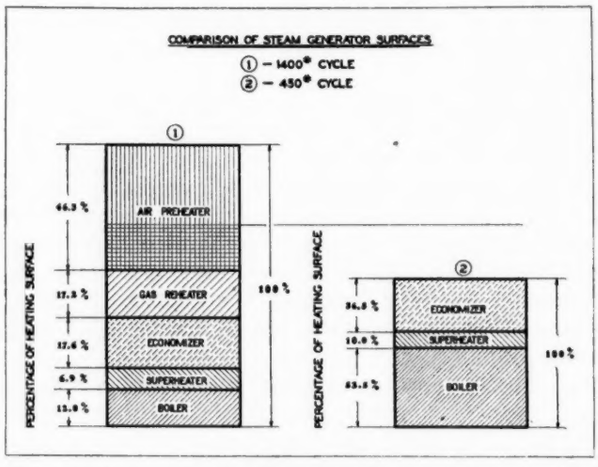

Chart showing comparison of steam generator surface for 1400-pound and 450-pound cycles respectively.

would be about 692 degrees Fahrenheit. Higher pressure boilers are thus less efficient than those operating at lower pressures. Why then do we go to higher pressures? The answer is this: By taking advantage of the fact that the steam is more dense at 1200 pounds than at 200 pounds, we are able to develop more kilowatts per square foot of boiler surface than with the lower pressure.

The ratios of surface in the boiler, superheater, reheater, economizer and air preheater to the total surface are entirely different for a 1200 pound design as compared to a 200 or 400 pound design. Twelve hundred pound surface costs more than 200 pound surface, but we use less of it and are able to work it at a higher rate. Other advantages of the higher pressure are the savings in the turbine room due to the smaller condenser and auxiliaries and a reduction in the capital expenditure for building.

The trend seems to be distinctly to boilers of greater capacities, making use of as high pressure and temperature as can be justified. Even where the higher pressure design is an even break from the standpoint of total cost of power, the decision

is usually in favor of the higher pressure because, if the design can be justified with the present price of fuel, it certainly will be justified in the future since the trend in the price of fuel is to a higher level. Further, the latest development will have a longer economic life than the older conservative design.

Table Shows Effect on Cost

The following is a table compiled by Frank Clark of the Stone and Webster Company, and J. B. Crane of the Combustion Engineering Corporation.

The table is very interesting in that it shows the effect on cost when the number of units is increased.

Number of Boilers	*4*	*6*	*8*	*12*
Sections per Boiler	60	40	30	20
Relative Building Area—Per Cent	100	112	127	133
Relative Investment Cost—Per Cent	100	112	124	142
Building and Foundations	16.10	18.4	20.4	24.3
Boilers, Superheaters, Settings, Etc.	32.0	37.0	42.9	54.0
Draft and Feedwater Systems	22.4	25.2	27.4	28.2
Piping	9.6	10.7	11.7	12.7
Fuel and Ash Handling	7.6	8.3	8.9	9.5
Fuel Preparation	9.6	9.6	9.8	9.9
Auxiliaries	2.7	2.8	2.9	3.4

Feedwater: One of the most important problems in power plant design is the proper treatment of feedwater. Change in the type of condensing equipment from jet condensers requiring 100 per cent boiler feed make-up, to surface condensers requiring only a small fraction of new water, has had its effect on the feedwater problem. The proper conditioning of feedwater before admitting to the boilers is more popular now than it was some few years ago.

In many plants, it was not uncommon to condition the water in the boiler itself by feeding with the raw water proper chemicals in the correct amounts. Although this treatment was better than none, it resulted in many cases in excessive blowdown and high maintenance in connection with feedwater lines and steam turbines.

The use of extended boiler surface in the form of water walls to reduce furnace maintenance where high rates of combustion obtain, together with the ever increasing demand for more steam per square foot of boiler surface, has made it imperative that make-up be properly conditioned before being introduced into the system. Higher steam pressures with increasing metal temperatures have made it necessary to supply a better quality of make-up than that required for the lower pressures.

Lime, soda, sedimentation basins, hot chemical processes, zeolite and evaporators are made use of in conditioning water for our modern stations. In some of the more recent installations where the water is unfit for boiler use without pretreatment, the raw water is first treated and permitted to settle, next passing through a zeolite system, thence to the evaporator, and thence into the boiler circuit.

This additional equipment, of course, means an increase in cost over a layout where no pretreatment is used, but this is more than offset by the decreased maintenance cost and the reduction in capital cost due to the ability to operate the boiler surface at higher evaporation rates.

The trend in present day design seems to be to pretreat all raw water and to supply the boiler with the best possible quality of make-up. Therefore, we can expect to see more and more of this type of equipment used. Indications are that a still higher quality of pretreatment will be demanded by operators.

Superheaters: Steam superheaters are now in common use. The old separately fired type has almost entirely disappeared. Cast iron protected elements have been used extensively as well as unprotected steel tubes. The use of the bare steel tube type seems to be on the increase at this time. The degree to which the steam is superheated has steadily increased since 1903, the limit until within the last five years having been set by the turbine manufacturer to protect the high pressure elements.

Maximum Total Steam Temperature Raised

In the United States until very recently 750 degrees Fahrenheit total steam temperature was considered the maximum despite the fact that plants had been operating successfully in Europe for at least five years at 850 degrees Fahrenheit. Today we understand that the manufacturers of superheaters will accept contracts for 900 degrees Fahrenheit. It is interesting to note that steam temperatures in excess of 1000 degrees Fahrenheit have been attained. At least one of the larger public utilities is pioneering in this field, having installed a plant to attain 1000 degrees Fahrenheit steam temperature. The turbine manufacturers no longer place a limit on the maximum temperature for which they will design. The general feeling is that any temperature that the superheater can develop can be taken care of in the turbine design.

There is little question that the trend in superheaters is to higher temperatures. This change will affect the whole economic picture of equipment. The effect must be to reduce the total cost of power, or otherwise the change will not be justified. It is too early to predict the general trend, as the maintenance cost of metal under high temperatures is yet to be determined.

Reheaters: Reheaters probably could be better designated as resuperheaters, as this is actually the work they perform. The reheater is not new. It was used with multi-expansion steam engines many years ago. Today we find it practically the same, the heating medium being either flue gases or steam as the problem dictates.

The resuperheater becomes a necessity where the pressure elevation is such that complete expansion of the steam cannot be accomplished in a single cylinder turbine with due regard for maintenance, without excessive moisture. This statement is based on present day practice, where 750 degrees Fahrenheit is considered the maximum

practical steam temperature. Present day practice indicates that the preference is for at least two cylinder turbines, if the operating pressure is in excess of 450 pounds and the total temperature does not exceed 750 degrees Fahrenheit.

If we succeed in supplying steam at any temperature considerably in excess of 750 degrees Fahrenheit, then the necessity for resuperheating becomes more remote. It will not be necessary at the pressure we have been accustomed to associate with reheat. The trend in this line of equipment is not distinct, but the writer feels with our present standards of pressure and the possibility of higher temperature steam available there will be a period in which there will be fewer reheater installations.

Economizers: An economizer is a feed water heater placed in the path of the exit flue gases from the boiler. As early as 1880 economizers were known in the United States, but were little used.

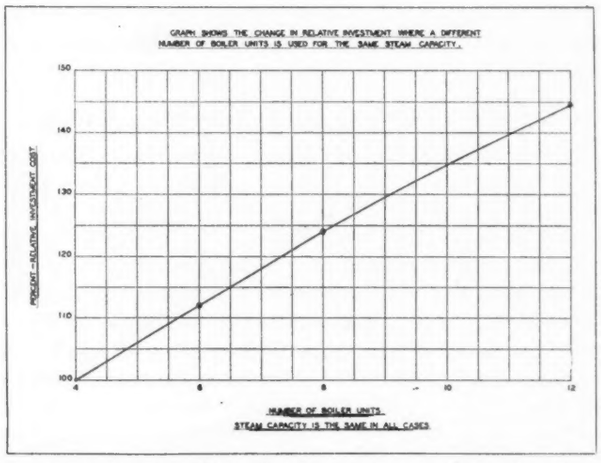

Chart showing the relation between per cent relative investment cost and number of boiler units.

The first installation in this country followed the English practice, making use of the cast iron tube type. This type was used until about 1920, when it was displaced by the steel tube type, the standard of today. The use of the steel tube type was made practical by the more general use of surface condensers and minimum air content water.

An economizer, if properly proportioned to boiler and bleeder feed heating surface, is justified economically. In any event, it serves as a check against corrosion in so far as boiler surface is concerned.

Economizer surface is always more efficient than the same amount of boiler surface for the same temperature because it involves forced circulation while boiler circulation is natural. By the use of a properly proportioned economizer, we are able to reduce the size of the boiler and to secure a better over-all boiler efficiency for the same investment.

The trend today is distinctly to larger economizers and smaller boilers, in some cases even to the extent of steaming economizers. The result of the installation of this equipment is a reduction directly and indirectly in the total cost of manufactured power.

Air Preheaters: An air preheater, as the name implies, is a heat exchanger whereby additional heat is added to air. Air preheaters were used in the United States as early as 1893, were then abandoned, and again introduced about the year 1920.

The object of this equipment is to increase the over-all efficiency of a boiler installation by recovering some of the heat in the flue gases that normally is discharged from the stack.

There are three principal types—tubular, plate and mass.

The tubular type is a box containing nested tubes so constructed that the air to be heated is forced against the outside of the tubes while the heating medium is forced through on the inside of the tubes. The air side of the unit is usually baffled in order to make it multi-pass.

The plate type of air preheater is constructed of plates arranged in a metal box in such a way that we obtain alternate lanes for passage of air and heating medium. The heating medium, which is usually flue gas, heats one side of the plate while the air on the opposite side of the plate absorbs the heat and is raised in temperature.

The mass type of heater is best represented by the Ljungstrom unit. This unit is usually a circular box divided into compartments, each compartment being filled with metal strips of shape and arrangement to offer maximum surface. The box revolves by means of a shaft through the center, through the path of the air and flue gases, so that the surface in the box is alternately heated and cooled by passing through the hot gases and the cold air streams.

Air preheaters may be justified from several angles other than the economy effected by the recovery of heat from the flue gases.

The air preheater is a necessity where higher steam pressures and extraction heating are used. This is the result of not having boiler surface available at a sufficiently low temperature in the path of the flue gases to reduce the temperature to a practical minimum. The decision whether economizers or air preheaters should be used with lower steam pressures is usually determined by the type and design of other major equipment. In some few cases of this kind both air preheaters and economizers can be justified.

In order to avoid the use of coal dryers where pulverized fuel is used and mill drying is necessary, the required heat is supplied by means of air preheaters. Where excessive rates of burning coal are required, preheated air may be helpful and, in some cases, a necessity. This type of equipment is relatively cheap surface compared to boiler or economizer surface. It is less efficient due to the relatively low temperature difference available.

The result of the use of this equipment is to reduce, either directly or indirectly, the station heat loss, reducing the total cost of a kilowatt-hour. The trend today is to install air preheaters wherever they can be justified economically. We are in a position to know whether or not air preheaters can be justified, as a result of our experience, being

better advised as to their performance, maintenance and proper limits.

Furnaces: Of all the equipment covered by this paper, probably no single item is more important or has undergone greater changes than furnaces. As late as 1895, our boilers were set only four feet above the grates, and it was claimed by certain manufacturers and users that, if, this distance were increased, heat, and therefore boiler efficiency, would be lost. This distance has continued to increase, however, and today it is not uncommon to find boilers set thirty feet or higher and operating at higher efficiency.

Other changes have taken place in furnace design, and one of the first introduced was the air-cooled furnace wall. The first installations of this type were built with no thought of making use of the heat picked up by the air traveling between the inner and outer walls, but to reduce maintenance.

The necessity for a wall of this type was further justified by the introduction of powdered fuel. The result of this development was the ability on the part of the operators to maintain higher rates of combustion per cubic foot, without any increase in furnace maintenance.

With boilers ever increasing in size and with the demand for further reduction in furnace maintenance, it soon became evident that the added expense due to a forced circulation of air through the walls could not be justified. These were the conditions that led to the application of water-cooled surface to further reduce furnace maintenance by a reduction in furnace temperature. These were indeed important steps, as not many years ago the period it was possible to keep a boiler in service was usually determined by the life of the furnace refractories, and very high furnace maintenance cost was the rule.

Water-cooled surface as a part of the boiler, first in the form of water backs and later as steel boiler tubes, was first applied to those zones of the furnace showing most punishment. The results obtained from these small patches of water-cooled surface were so gratifying that the amount of cooling surface was gradually increased, until today we have many installations of furnaces completely water-cooled. In many cases, it has been found that the completely water-cooled furnace was not satisfactory. The amount of water-cooling surface required for the maximum over-all furnace and boiler efficiency, with due regard for maintenance, must be determined after careful consideration of the furnace efficiency required, the kind and quality of coal, character of ash, method of firing, type of ash disposal, and the ratings to be carried.

Both the air-cooled and water walls are successfully used today, and the limiting factors affecting their performance and determining the field of their application have been worked out for most grades of fuel. The trend for central station practice is to water-cool the furnaces, reducing furnace maintenance through a reduction in the furnace temperature by the absorption of radiant heat by the water-cooled surface. The amount of cooling surface installed, however, is determined only after careful weighing of the combined effect of the various factors entering into the particular problem. The effect of this development has been to reduce the cost per kilowatt-hour, by making possible a reduction in building cost and a decrease in the furnace maintenance cost, as well as an increase in the availability of the equipment.

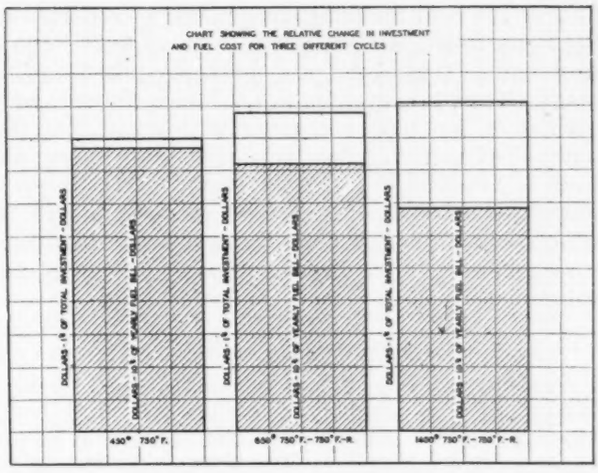
CHART SHOWING THE RELATIVE CHANGE IN INVESTMENT AND FUEL COST FOR THREE DIFFERENT CYCLES
DOLLARS - % OF TOTAL INVESTMENT - DOLLARS
DOLLARS - % OF YEARLY FUEL BILL - DOLLARS
450° 750° F.
650° 750° F. – 750° F.-R.
1400° 750° F. – 750° F.-R.

Chart showing relative change in investment with respect to fuel cost for three different pressure cycles.

Fuel Burning: The past ten years have seen the mechanical stoker grow from a small, light, simple machine capable of burning an average of 18 pounds of coal per square foot of stoker surface, to a gigantic machine capable of burning 70 to 80 pounds per square foot of grate surface. The most recent stoker contract calls for heat release to develop 530,000 pounds of steam per hour. This stoker will be 15 retorts wide, 26 feet ½ inch, and 69 tuyeres long, 26 feet 8 inches, with a fuel bed of 694 square feet.

From 1920 to 1923, a number of pioneer pulverized fuel installations were made, and for a time the trend seemed to be away from stokers. Like all new developments, pulverized fuel was installed not only where it was justified but also where conditions warranted other methods of firing. The result has been a number of misapplications.

Both pulverized fuel and stoker installations are now successful, and all indications are that there is a reasonably definite field of application for each. We now choose our fuel burning equipment much more carefully than we have done in the past. No doubt this is due to the fact that we are more familiar with the limiting factors affecting the equipment.

With the increasing capacities of boilers, the manufacturers of fuel burning equipment in many cases have found it difficult to expand their present designs to the required capacities and have been forced to develop new designs. The equipment available today is undergoing not only a period of development but also a refining process which should result in a reduction of first cost as well as maintenance cost.

Using as the basis of an opinion the 1930 sales

figures for coal burning equipment, as reported to the Department of Commerce, there appears to be a preference for stokers over pulverized fuel equipment. This, however, is not a fair indicator, as a review of the past six years will show that the amount of boiler surface equipped with pulverized fuel is considerably greater than that equipped with stokers. The result of this development in connection with fuel burning equipment has been a reduction both in direct and indirect costs, and, consequently, in the cost per kilowatt hour.

Changes in Auxiliary Equipment

Auxiliaries: The writer has endeavored to treat individually a number of classes of equipment, representing the greater part of the total cost of the mechanical equipment. There remain a greater number of pieces of equipment which individually represent a smaller part of the total cost, such as boiler feed, condensate, circulating and service pumps; air and oil coolers, piping, valves, regulating and control equipment, which in this paper will be classified and discussed under the general heading of auxiliary equipment.

Forced and induced draft fans are included in this group but, judged in the light of recent installations, should be classified as major equipment. It is not intended to infer that this equipment is not of sufficient importance in the mechanical set-up to merit individual discussion. The grouping has been made to conserve time.

During the past ten years, many changes have taken place in auxiliary equipment. Many new designs have been developed; existing designs bettered; capacities, efficiencies and reliability increased; and maintenance minimized. Obviously, these changes in most cases resulted from the requirements of the primary equipment, such as turbines and boilers. Although the manufacturers of auxiliary equipment have shown a readiness to cooperate and meet the demands of the times, we can point to periods where the rate of development has retarded the adaptation and perfection of new and revised cycles.

Development is very expensive, and many times we find the small manufacturer of auxiliary equipment, whose margin of profit is dependent upon volume, reluctant to develop and perfect new and untried designs because of absence of definite market and inability to secure commensurate prices.

In some cases, lagging development in certain lines can be attributed to either lack of experience or an absence of suitable materials.

Today the designer has at his command a wider choice of auxiliary equipment than ten years ago, so that he can take advantage of steam or electric drives for best application, proper speeds for best efficiency, and elaborate control equipment.

It is now possible to make our heat cycles more flexible and more efficient over a wider range of load. The first cost of auxiliary equipment in most cases has increased during the past ten years, but this is more than offset by better efficiency, lower building cost, and a reduction in maintenance charges.

Conclusion: By a review of the trend of the design of mechanical equipment, I have attempted to show the true economic trend. The effect of these changes in design during the past ten years has been to reduce the fuel and heat units necessary to develop a kilowatt-hour from an average of 3.4 pounds of coal, 46,000 B.t.u., to an average of 1.7 pounds of coal, 23,000 B.t.u. The lowest heat rate obtained to date under variable load conditions for a central station is about 12,500 B.t.u. per kilowatt. Obviously, the heat rate of a station does not tell the whole story unless this figure is considered in conjunction with load and capacity factor, unit price of fuel, fixed and operating charges. It should be emphasized that the increase in thermal efficiency indicated above has more than offset any increase in total investment.

In all cases, such changes as have taken a permanent place in design have either directly or indirectly reduced the ultimate cost of generating electrical energy. Most of us will agree that this is a statement of fact and can be substantiated by our own experience. However, a further proof of this is indicated by figures compiled by the statistical department of the N.E.L.A., which show that the cost of steam generating stations has decreased 12 per cent during the past eight years. It is indeed interesting to note that this reduction has been accomplished by those responsible for design, in spite of more exacting demands on the part of the public with respect to service and on the part of the operator with respect to reliable and spare equipment.

Continued reduction of the fuel rate of generating stations of the order experienced during the past ten years is hardly to be expected, as it must be appreciated that we are ever dealing with a decreasing increment. Until such a time as those responsible for design are able to develop new cycles, new materials, or new methods affecting principally the first cost of our generating stations, we should expect no further phenomenal reductions. It would appear, however, that the public utility industry as a whole can be expected to benefit by applying and further perfecting the performance of equipment now available to meet the individual problems.

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General Electric Company announces the appointment of John Anderson, assistant to J. G. Barry, vice-president, as secretary of the sales committee of the General Electric Company. Mr. Anderson succeeds E. G. Waters, who is retiring at his own request on the completion of more than 42 years' continuous service, the past 25 being as secretary of the sales committee.

On graduating from Lehigh in 1910 Mr. Anderson entered the General Electric test course at Schenectady and has been associated with that company in various positions up to the time of his present promotion.

Coal Drying for Combustion

Two Notable British Machines Operating on New Principles

By DAVID BROWNLIE, LONDON

As the author states in the early part of his article, the predrying of pulverized coal is no longer practiced except with fuels having a very high moisture content. The rapid advances made in mill-drying have made this method almost universal. However, in burning lignites and coals high in moisture, it is still necessary in most cases to effect at least partial drying before the coal enters the mills. Various types of equipment for this purpose have been developed and used. Mr. Brownlie describes two driers recently developed in England for which very creditable results are claimed.

IT is well known that the almost universal practice in connection with pulverized fuel firing at the present time with average bituminous coals is to dry direct in the pulverizer by means of a stream of heated air or combustion gases, or mixtures of these, at any desired temperature such as 250 to 300 deg. fahr. That is, separate driers for bituminous coal up to say 10 to 12 per cent moisture, whether of the rotary cylindrical type or otherwise, are no longer standard practice, although many plants of this description are still operating.

For wet coals, however, such as 12 to 15 per cent moisture or over, it is the opinion of many fuel technologists that separate drying is necessary, although certain types of unit pulverizer will take coal up to 20 to 25 per cent moisture. Also it is obviously necessary to use the separate drier in the case of raw lignite, which in many areas of the world contains 50 to 65 per cent moisture as mined and has to be dried down to the hygroscopic limit of about 15 to 16 per cent before it can be used for pulverized fuel firing. Such fuel is being used in a number of plants in Germany and to a limited extent in the United States.

So far as mechanical stoker operation is concerned, the pre-drying of coal is practically never adopted, but in the opinion of the writer this is a field for economy that should be investigated in connection with the operation of very large power plants. If we assume for example, on the most conservative basis, that a given average bituminous or semi-bituminous coal, as delivered, contains 7.5 per cent moisture, this means that in the case of power stations burning 2000 tons of coal per 24 hr., 150 tons of water have to be evaporated. Obviously this means a definite heat loss, because all this water has to be evaporated to steam in the fires and the steam subsequently escapes from the plant superheated to the temperature of the waste combustion gases, while another trouble is the increased tendency to corrosion, especially when using a high sulphur content coal. In many cases also the amount of water in coal as burned exceeds 7.5 per cent, and there must be a comparatively large number of power stations in the world evaporating 150 to 250 tons of water per 24 hr.

There seems to be no question that a reduction in the moisture content of raw coal from say 7.5 to 3.0 per cent would result in a considerable improvement, and while admittedly the main objection is the net capital and operating costs of the drying plant and the extra complications involved, including increased plant space, the subject is worthy of serious study.

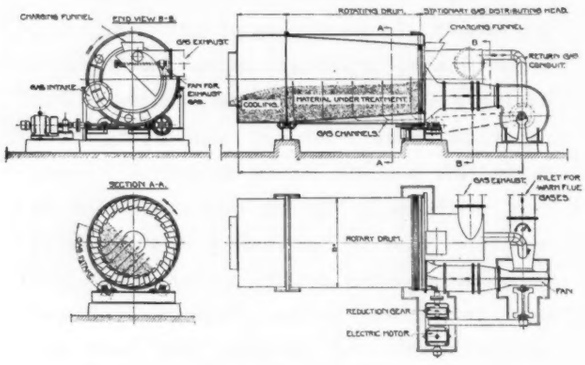
For the most part, of course, the drying of coal, as well as of a very wide range of other substances, is carried out either in rotary cylindrical driers or in rabble arm machines, in which the material in a thin layer is scraped over a flat floor of metal, generally heated from underneath. Also the familiar long rotary horizontal or slightly inclined cylindrical drier may be internally or externally heated, or operated according to both methods.

It is the object of the present contribution to describe two new British drying plants which operate on ingenious principles that have not hitherto been used on an extended scale for drying, that is the "Rotary Louvre" drier of Dunford & Elliott (Sheffield) Ltd., Sheffield, and the "Universal" drier of the Brightside Foundry & Engineering Co. Ltd., also of Sheffield, both of these driers being particularly intended for coal, although applicable to many other substances.

The Rotary Louvre drier is the invention primarily of A. P. Pehrson, a Swedish engineer, very long resident in the United Kingdom, who is a Director of Dunford & Elliott (Sheffield) Ltd.

Essentially the design consists of a short horizontal, slightly inclined, wide diameter, gear-driven rotary steel-plate cylinder, having inside a concentric cylinder of lesser diameter, formed with a series of longitudinal louvres. The coal or other material travels through these rotary cylinders in

the ordinary way, with an additional sluicing action, and, by a special device, heated air or combustion gases at any desired temperature are caused to pass through the louvres but only beneath the surface of the material itself, on the same gen-



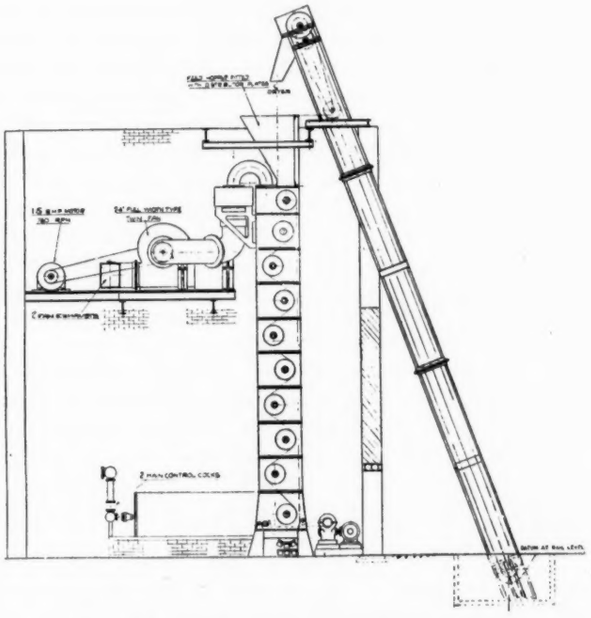
Plan, Elevation and Sections of Rotary Louvre drier.

eral lines that gas is bubbled through water by means of a tube. As a rule the amount of material is arranged to occupy about one-third of the total space in the inner louvre cylinder, and if a cross-section is viewed with the motion of the cylinder in a clockwise direction, then the charge at any given time is always occupying a position in the cylinder which is caused by the piling-up of the material on the left side in the direction of the rotation, although of course each individual particle is continually rolling over and falling down again by gravity.

The arrangement is such that as the cylinder rotates the combustion gases—from any convenient gaseous, liquid or solid fuel, mixed also with excess air if necessary, or using heated air alone—only pass through those louvres that are beneath the surface of the charge, that is corresponding to about one-third of the total louvres on the left hand side in the direction of the rotation, so that, as indicated, the heating medium can only pass into the cylinder through the body of the charge itself and not by way of the louvres that happen to be above the charge.

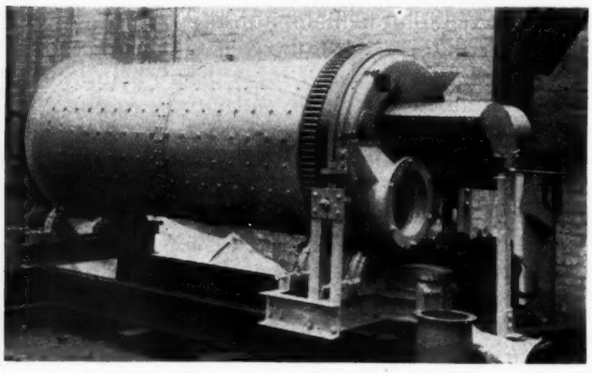
The advantages claimed for this method are in the first place a high efficiency because the whole of the drying medium is brought into direct effective contact with the material; also this increased efficiency means a smaller installation for a given throughput, while the speed of rotation can be extremely small, generally not more than about one revolution per minute, which reduces breakage and disintegration of the coal or other product being dried and means relative freedom from dust and small power consumption. Further, accurate control is given as regards operating conditions, especially that of temperature, so that another claim is lessened liability to fires because of spontaneous combustion, and also no appreciable loss in coking properties in the case of bituminous coals, particularly with a high volatile content.

On the usual lines the construction is of mild steel or any other suitable material, with outer rims or tires which run on two heavy roller bearings, while the drive is by means of gear wheels, including one main gear wheel round one end of the cylinder. allowing of effective speed reduction.



Elevation of 40 ton per hr. Universal drier.

Also for motor driving, the most convenient method, there is supplied a suitable totally-enclosed reduction gear, the motor also driving the fan or blower for discharging the hot gases to the conduits between the outer cylinder and the inner louvre cylinder, which is cone-shaped and at this point is of lesser diameter. Further, the discharge end of the drier is arranged as a cooling zone, the material passing in through a hopper at the opposite end and traveling through by gravity to the cooling zone. The hot gases enter by way of a gas intake in a stationary head, to which also is fixed the hopper. The gases can only pass to about 20 to 25 conduits or compartments that are formed between the two cylinders and which discharge to the corresponding louvres, while further there is an arrangement whereby any proportion of the discharged moisture-laden gases can be returned to the circuit. The whole cylinder is fixed in a hori-



Rotary Louvre drier 9 ft. 10 in. long and 3 ft. 11 in. dia.

zontal position, which has the advantage of doing away with end-thrust problems.

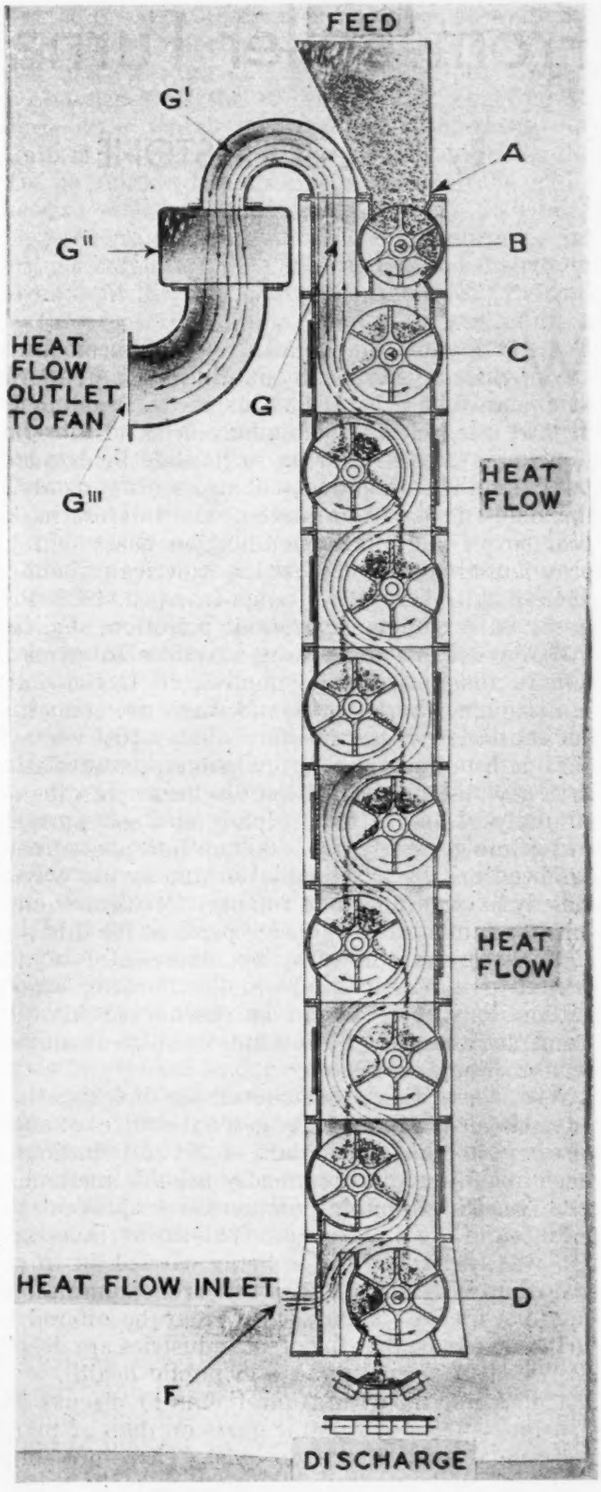
Standard Rotary Louvre driers of this kind are made from 2 ft. 6 in. to 11 ft. 2 in. dia., and up to 26 ft. in length. As typical of the efficiency obtained, it is stated that a given drier, 11 ft. 2 in. dia. and 23 ft. long, is evaporating nearly 4 tons of water per hour, using waste combustion gases at 550 deg. fahr. The drier is claimed to be particularly suitable for coal before pulverizing and also for the treatment of slurries. With regard to dust troubles, it is stated that the gases pass out over a wide area of surface with a speed of only about 1 ft. per sec. Very satisfactory results are said to be obtained with lignite, peat, wood chips, wood pulp, and sawmill refuse, apart from many other materials of a non-combustible character, while a new field is the drying of grass and other agricultural produce.

A detailed test also on a Rotary Louvre drier with coal, conducted in a small plant installed at the Fuel Research Board in London, with a throughput of 1.25 tons of coal per hour, shows a moisture reduction from 9.40 to 0.95 per cent, using 1100 cu. ft. of very hot flue gas per minute at a temperature of 880 deg. fahr., the design being particularly intended for good coals or other material where it is desired to get an extremely low final moisture content of say less than 1.0 per cent.

The "Universal" drier is the invention of Mr. R. V. Farnham of the Brightside Foundry and Engineering Co. Ltd., and has only just been introduced. In general the arrangement consists of a high, vertical, cast-iron casing with a furnace installation at the bottom, and inside the casing is a series of horizontal rotary elements with six projecting arms on the "spider" principle, carried upon a shaft, each of which is driven by a gear wheel and chain at one end of the casing.

The damp coal or other material enters through a hopper at the top and passes down into the first compartment of one of the 6-compartment rotating spiders, also known as "retarders," each of which empties in turn from the bottom as the shaft revolves and drops the material down into one of the six compartments of the next spider and so on. In this way the material gradually passes downwards through the whole setting from one rotating compartment to the other until it is finally discharged at the bottom by the last spider on to a traveling belt conveyor. The heating gases enter at the bottom and pass up through the casing, heating the coal mainly on the internal principle, while the wet, moisture-laden gases are discharged from the top. The gases are handled by an induced draft fan.

A Universal machine of this character with a normal throughput of 40 tons of average bituminous coal per hour, is operating at the Barrow Colliery of the Barrow Hematite Company in the North of England, and has been tested by Mr. R. A. Mott of the Department of Fuel Technology, Sheffield University, who has issued a most complete report. Among the advantages claimed for this apparatus are high heat-transmission efficiency, small floor space, and low power consumption. Thus in the above case the plant removes 5 per cent moisture



Vertical section of Universal drier.

from 42 tons of coal per hr.. while the floor space is only 16 ft. x 14 ft., the power being 19 hp. total, that is 17 hp. for the induced draft fan

(Continued on Page 51)

The Elimination of Sulphur Compounds From Boiler Furnace Gases*

By H. F. JOHNSTONE†
Urbana, Illinois

Articles on this subject have appeared in several issues of COMBUSTION. For the most part they have dealt with European practice and more especially with conditions in London where the question has become a matter of serious public concern. The author of this paper has been conducting extensive research at the University of Illinois Engineering Experiment Station and in this paper presents his findings to date. This work has disregarded methods of sulphur removal based on absorption by solid surfaces because they exceed the practical limits of draft loss and has been devoted primarily to investigations of methods involving the washing of flue gases with water or an aqueous solution of some chemical. With this method as applied in England, using water, the principal objections were the amount of water and time required for removal. It was, therefore, decided to experiment with additional reactions using various catalytic agents, whereby the dissolved sulphur dioxide could be removed from the solution thus decreasing the time of contact and the volume of water required. The results of these experiments, as given in this paper, indicate the possibility of substantial improvement along these lines.

WITH your indulgence I would like to introduce my subject by quoting from an address of a man whose contributions to the development of coal research and technology need no introduction here. I am referring to the late Professor S. W. Parr. The quotation will also serve to establish the date of the beginning of my interest in the problem of sulphur in combustion gases. In his presidential address[1] before the American Chemical Society in session at St. Louis in April, 1928, Professor Parr, commenting on air pollution, suggests, "We have made marvelous advances in cures of human ills, in bacterial control, in hygiene and sanitation so far as water and waste are concerned but sanitation of the air stands today just where it did one hundred years ago. In fact, air sanitation is in a worse plight, for the discharge into the air annually of smoke and sulphur and ash particles and grime generally, from 600 million tons of coal, has been met by practically nothing in the way of remedy." And, to quote further, "If we assume a sulphur content of less than 2 per cent for this type of fuel, you may see, by the exercise of a little mental arithmetic, that from the burning of 600 million tons there would be discharged into the atmosphere over 20 million tons of sulphur dioxide or 40 billion pounds."

With these as a background, the investigation[2] was extended to include the general subject of stack gases with the particular object of finding a mechanically and economically feasible method of removing the sulphur compounds to prevent the pollution of the atmosphere. This entire investigation was instigated and is being carried on in cooperation with The Utilities Research Commission, Inc., of Chicago—a fact which may be offered as further evidence that the great industries are deeply interested in air pollution and public health.

It does not lie within our theme to discuss the injurious effects of sulphur gases on man or plant, nor even if such effects do exist. There are some who state that these gases actually may be beneficial in the cure of tuberculosis. It will suffice to agree that when a feasible method of sulphur elimination is found industry will readily accept it. It remains, therefore, for this age of science and mechanical skill to develop the fundamental details of the process and their practical application.

Before starting our discussion it will be well to survey the situation as a whole.

It is of interest to note that of the half-billion tons of coal mined in the United States in a year the railroads consume 25 per cent.[3] We should

* Published by permission of the Director, University of Illinois Engineering Experiment Station. Presented before the Third International Conference on Bituminous Coal, Pittsburgh, Nov. 16 to 21, 1931.
† Special Research Assistant Professor in Chemical Engineering, University of Illinois.
[1] Parr, *Ind. Eng. Chem.*, 20, 454 (1928).
[2] Johnstone, *Univ. Illinois Eng. Expt. Sta. Bul. 228*, (1931).
[3] Tryon and Rogers, *Proceedings of the Second International Conference on Bituminous Coal*, 1, 139 (1928).

observe, however, that a large portion of this is burned outside of the cities and congested centers. Ranking with the railroads and consuming an equal amount is domestic consumption, in which we might include the heating of large buildings, such as hotels, apartments, stores, etc., and very small industrial consumers. Here again, assuming about an equal distribution of population between rural and urban districts and regarding the latter as slightly larger consumers of coal, we would expect that about 15 per cent of the total coal is used for domestic consumption in the cities.

The next class of users in percentage of consumption is the general manufacturing group which consumes 21 per cent of the total—largely in the congested centers. The coke ovens and iron and steel group absorb about an equal quantity, but because of their methods and the type of coal used, they hardly can be held responsible for sulphur pollution.

Ranking fifth and consuming 8 per cent of the total is the electric power industry. Because of the great centralization of this industry, often in the populous centers, this group should be included with the railroads, general manufacturers, and domestic consumers as a source of the atmospheric sulphur compounds.

It will be obvious at the start that there are two lines of attack on this sulphur problem: first, that in which an endeavor is made to remove the sulphur compounds prior to burning, such as by the preparation and processing of the coal; and second, that in which the combustion gases are treated for the removal of sulphur compounds. It will also be obvious that, at least for the small consumer, only the former procedure is applicable to the domestic group, and that the others, railroads, manufacturers and electric utilities, may use either method.

The Cleaning and Processing of Coal

Admitting that a solution to the problem for the domestic consumer might lie in a choice of fuel, such as gas, oil or low sulphur coal, it is nevertheless exceedingly doubtful that such a solution could be considered for the other three groups. In other words, coal will continue to be burned, and as the higher types are consumed the lower grades with their greater percentage of sulphur would come into use—in fact, are coming into use today.

The fact that besides a partial removal of the sulphur there are many other advantages to be gained by cleaning coal makes it surprising that this operation has not been adopted more extensively than it has. Yancey and Fraser[4] state that in 1927 approximately 22 million tons of coal were washed in the United States, equivalent to 3.8 per cent of the total output. Of this quantity fourteen and one-half million tons were washed in the State of Alabama alone where a large proportion of this fuel is used for the manufacture of iron and steel. In Illinois, Indiana, Ohio, West Virginia, Pennsylvania and Kentucky less than 2 per cent of the total coal mined is subjected to washing operations. In England, during the same year, 51 million tons, or 20.5 per cent of the total output, was cleaned.

Because of the many papers on this subject contributed to this and other conferences, as well as to the technical press, it will not be necessary to discuss coal cleaning in detail. At the present state of knowledge of the composition of coal the absolute limit which any method of cleaning may attain is the removal of segregated impurities that exist as more or less discrete particles in the coal at the size selected for cleaning. Finely distributed ash particles and sulphur and other inorganic impurities combined with the carbon and distributed throughout the coal cannot be removed. Evidently, therefore, the limit of sulphur reduction in many cases is less than 50 per cent of the total sulphur present. However, even a small reduction by this method should be regarded as of economic importance in the sulphur problem. In view of this and of the scarcity of fundamental knowledge of the organic sulphur compounds it would appear that research on the nature and properties of these compounds is highly desirable.

The processing of coal for the production of power has received some attention in this country but its economic advantage in view of cheap and available natural gas must be proven more definitely before it can be extensively adopted. By the carbonization method, unfortunately, the total reduction of sulphur, considering the solid residue and the purified gas, is not over 40 per cent. With the development of means of removing sulphur compounds from fuel gases it would seem that these methods eventually can be considered as a means of reducing sulphur pollution. In the meantime the elimination of a greater percentage of the sulphur from the carbonized residue should be sought. This does not enter into the question, of course, if the fuel is to be completely gasified.

It should be mentioned in passing that the elimination of sulphur previous to combustion is not being overlooked in our research program, and that fully one-half of our efforts are directed towards this end. This part of the problem is under the direction of Dr. R. D. Snow who has obtained very interesting results on a laboratory scale in the removal of as much as 80 per cent of the sulphur from a 5 per cent sulphur coal.

The Reactions of Sulphur Compounds in Boiler Furnaces

Turning our attention now to the other end of the problem. i.e., the removal of the sulphur compounds from the combustion gases, it will be well again to make a survey of the conditions present. Taking the extreme case of a modern central power station, we see a boiler which burns 15 to 20 tons of coal an hour and generates up to 200,000 lb. of steam at a pressure 700 to 1700 lb. per sq. in. at a temperature of 800 deg. fahr. The flue gases, which contain 14 per cent CO_2, 4 per cent O_2, and 6 per cent water vapor, amount to 7½ million cu. ft. an hr., or 125,000 cu. ft. a min. So great has been

[4] Yancey, Fraser, and Thomas, *Bur. Mines Bull. 300* (1929).

the centralization in this industry that as many as 50 boilers may be in operation in one plant. Five thousand tons of coal will be burned in 24 hours. If we combine these facts with the following we understand the magnitude of the problem. Many of the coals used in the power plants, especially in the Middle West, are the so-called poorer grades and will contain as much as 14 per cent ash and 4 per cent sulphur. Five thousand tons of such coal, therefore, represent 200 tons of sulphur, or the equivalent of 400 tons of sulphur dioxide, or 610 tons of sulphuric acid. In addition to this, there are approximately 150 tons of iron oxide, 150 tons of alumina, 300 tons of silica, 100 tons of calcium and magnesium oxides and smaller amounts of compounds of the alkali metals and of phosphorus, manganese, vanadium, titanium and others. All of these are present in the ash in various chemical combinations. Of this ash, from 15 to 20 per cent passes out as dust along with the gases when the coal is fired on a stoker. This amount may be increased to 75 or 80 per cent, however, when the pulverized system of firing is employed.

A careful study of the flue gases has shown that between 70 and 95 per cent of the sulphur in the original coal is converted into gaseous compounds, of which only 2 to 3 per cent is sulphur trioxide. The concentration of sulphur dioxide in the gases, therefore, averages between 0.3 and 0.4 per cent by volume.

The first consideration that must be made in the removal of the sulphur compounds from this enormous quantity of gases is a mechanical one. The process must not materially interfere with the operation of the boiler. This places a limit on the draft loss involved in the cleaning apparatus which practically exists in the range of 0.5 to 1.0 inch of water. Furthermore, since the sulphur dioxide exists as gas molecules it cannot be removed by centrifugal or electro-static action. Should it be possible to convert the gas into sulphur trioxide, which would then combine with the water vapor present to form a mist of sulphuric acid, a removal might be accomplished by such devices. A study of the conditions in boiler furnaces shows that this conversion is not favored by the high temperatures and the very short interval of time the gas has for contact with any catalytic material. Actually, even when the original sulphur in the fuel exists as sulphuric acid, as for instance in petroleum wastes, it is practically entirely converted to sulphur dioxide in the furnace.[5]

The Washing of Flue Gases

Disregarding any method of removing sulphur based on absorption by solid surfaces as exceeding the practical limits of draft loss, the only remaining method is that of washing the gases with water or an aqueous solution of some chemical. Now the solubility of a gas in water depends on the characteristics of the gas, on its partial pressure, or concentration, and on the temperature of the water. Thus, while sulphur dioxide may be classed as moderately soluble in water, its concentration in a solution in equilibrium with gases containing 0.3 per cent is only 5.8 lb. per 1000 gal. at 80 deg. fahr. On this basis we would require 21,000 gal. of water for removing 75 per cent of the sulphur from 1 ton of coal containing 4 per cent sulphur; and since the solubility decreases as the temperature rises, this would be increased to 57,300 gal. at 125 deg. fahr. Furthermore, since the velocity of absorption of a gas is proportional to the percentage of saturation in the liquid the time of contact, even with counterflow, must be very long.

The investigations of the London Power Company[6] in connection with their new Battersea Station have brought out several important facts in regard to washing flue gases with water. In the first place we find that, although in actual practice, some secondary reactions take place which tend to reduce the amount of water required, the values given above are approximately substantiated. Thus, in order to remove 44 per cent of the sulphur dioxide from the gases from a 0.90 per cent sulphur coal, 6500 gal. of water are required per ton of coal. When the boiler is operating under half load, this amount is increased to 12,000 gal. for 67 per cent removal. The size of the scrubber can be gathered from the fact that 8.5 and 13 seconds' contact, respectively are required to obtain these results.

There are some theoretical considerations in the problem, however, the practical results of which were strikingly brought out in the work at London. It is immediately apparent that if the dissolved sulphur dioxide could be removed from the water at a rate equal to, or greater than the rate of absorption the capacity of the water should be greatly increased, thus decreasing the volume required for washing the gases. And further, since the liquid would remain at approximately zero per cent saturation, the rate of absorption would be the high initial rate of solution of sulphur dioxide and hence a much shorter time of contact should be required. There are three possible reactions by which the dissolved sulphur dioxide could be removed from the solution, viz., (a) neutralization with an alkali to form a bisulphite or sulphite salt, (b) reduction to form free sulphur, and (c) oxidation to form sulphuric acid.

The use of an alkaline solution to dissolve acid gases of course is not new. The chief difficulty in our case, however, lies in the cost of the chemical because, once neutralized, it is lost for further use and its only value is in the form of a possible by-product. In the experiments of the London Power Company it was shown that a final washing with an alkaline sodium carbonate solution would raise the efficiency of the washing process from 67 to 97 per cent when the boiler was operating at half-load, and the volume of water required was reduced to 3240 gallons per ton of coal, the time of contact remaining at 13 seconds.

In our own experiments we have found that a suspension of lime in the wash water nearly dou-

[5] Johnstone, *Ind. Eng. Chem.*, 23, 620 (1931).

[6] Report of Advisers to London Power Company, Ministry of Transport, Interim Rept. Nos. 3442 and 3714, 1929 and 1930.

bles the efficiency of a washer for a given time of contact and, using a special design of washer, the data indicate that 75 per cent of the sulphur compounds in the flue gases can be removed in a contact time of one-fifth of a second. In the neutralization the lime was converted to calcium sulphite and not calcium bisulphite as might be hoped. This means that the ratio of lime required to sulphur dioxide in the gases is 56 to 64 lb. instead of 56 to 128. Thus to remove 75 per cent of the sulphur from a ton of 4 per cent sulphur coal we would need 105 lb. of calcium oxide or 187.5 lb. of limestone.

The second possibility of chemically removing the dissolved sulphur dioxide lies in the catalytic reduction to free sulphur. Of the three possibilities, this is the most attractive from the standpoint of the by-product formed, for the sulphur is precipitated in the solid form in which it has some value or can be disposed of more easily than a liquid or gas. Several attempts have been made to use this principle on smelter fumes, such as Young's Thiogen process,[7] but these have usually consisted either of bringing the gases along with a gaseous reducing compound into contact with a solid catalyst, or of a cyclic process in which the sulphur dioxide is first fixed and then reduced in a later stage, after which the catalyst is regenerated to start the cycle again. Such a procedure would hardly be suitable for flue gases as it is to decrease the volume of water and time of contact that we wish to remove the sulphur dioxide as fast as it dissolves. The obvious difficulty is the relatively large quantity of oxygen in flue gases, which has a higher oxidizing potential than sulphur dioxide. The idea should not be entirely discarded, however, for it may be possible to make use of the very much higher rate of solution of sulphur dioxide compared to that of oxygen to bring about a separation. It would only be necessary to find a reducing agent that would react readily with sulphur dioxide and which could be regenerated easily and cheaply from its oxidized form.

The Use of Dissolved Oxidizing Catalysts

The third possibility of increasing the capacity of water for absorbing sulphur dioxide is the catalytic oxidation of the dissolved gas by bringing about a fast reaction with the dissolved oxygen from the flue gases. This method would convert the sulphur into sulphuric acid in which form it may or may not be useful, depending upon its concentration, degree of contamination and extent of supply. Catalysts for this reaction have long been known. Deacon, in 1871, showed that a mixture of sulphur dioxide and air in the presence of copper sulphate is converted to sulphuric acid. Later the same invention was made by Roessler and was specially applied to the absorption of acid smoke. Wyld states that the process is hardly applicable to the manufacture of sulphuric acid, but possibly to that of copper sulphate from waste sulphur dioxide. The same process, extended to include salts of manganese, iron, and tin, was patented by Clark in 1888.[8] Recently Ralston, Leaver and others[9] developed a method for oxidizing the ferrous sulphate in spent leaching solutions to ferric sul-

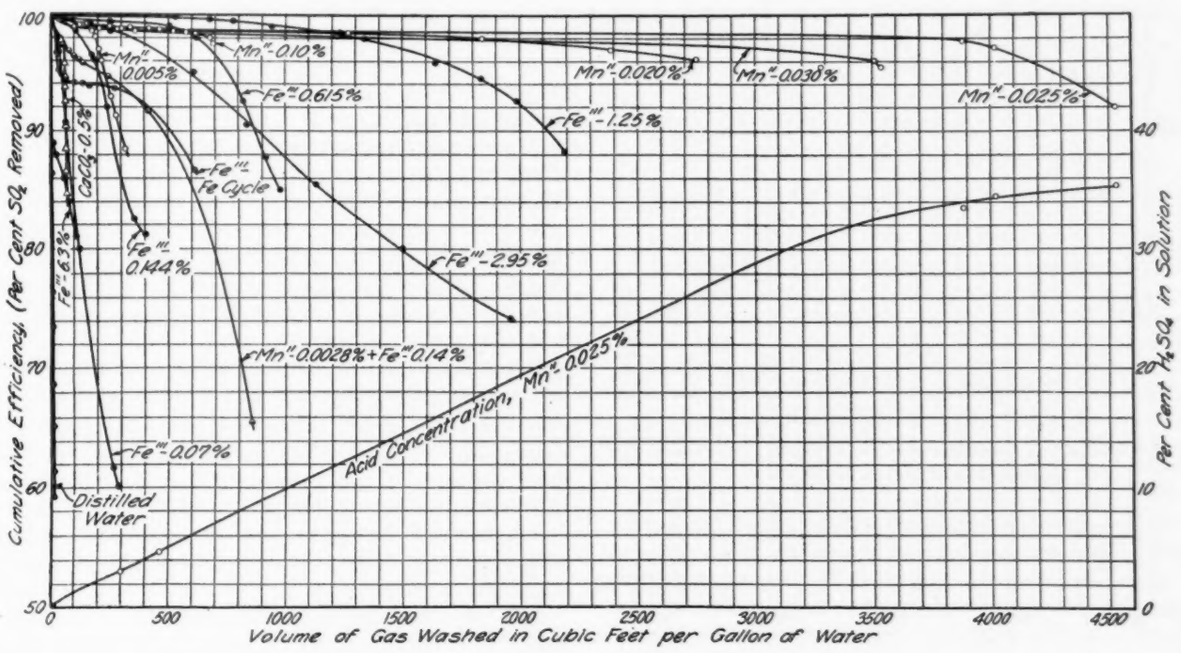


Fig. 1—Effect of metallic ions on capacity of water for absorbing sulphur dioxide from air mixtures containing 0.325 per cent sulphur dioxide

[7] S. W. Young, *Trans. Am. Inst. Chem. Eng.*, 8, 81 (1915); U. S. Pat. 1, 262, 295. G. J. Young, *Eng. Mining J*, 131, 7 (1931) Boswell, Can. Pat. 308, 238.

[8] Wyld, "Manufacture of Sulphuric Acid," II, p. 388.

[9] Ralston, Bur. Mines Bull. 260 (1927). Leaver, and Thurston, *Bur. Mines Rep. Investigations*, 2556 (1923).

phate by using air containing a small percentage of sulphur dioxide from smelter fumes. They noted that, after the iron was almost entirely oxidized, the sulphur dioxide and oxygen continued to be absorbed with the formation of sulphuric acid. In the experiments of the London Power Company, first evidence that catalytic oxidation was taking place was observed when wash water at 145 deg.

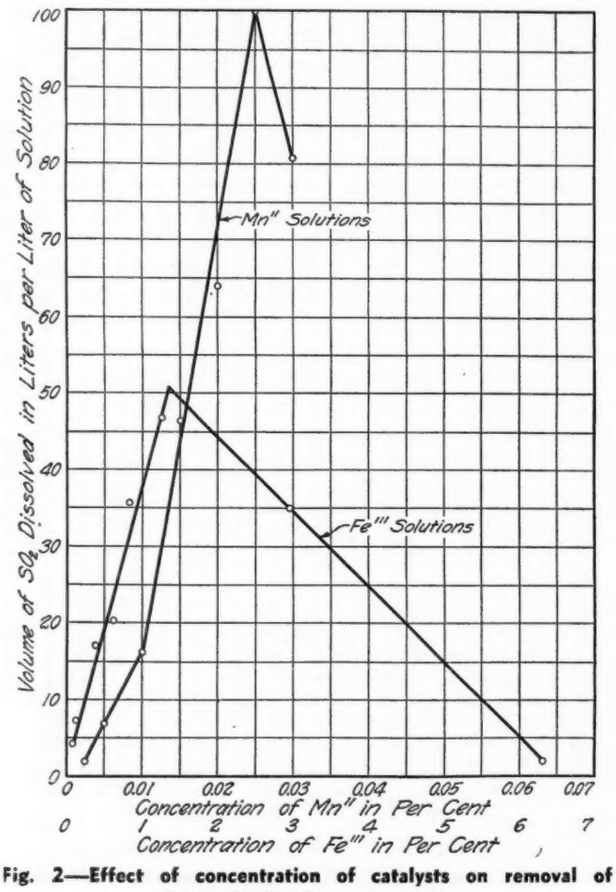

Volume of SO_2 Dissolved in Liters per Liter of Solution
Mn'' Solutions
Fe''' Solutions
Concentration of Mn'' in Per Cent
Concentration of Fe''' in Per Cent

Fig. 2—Effect of concentration of catalysts on removal of sulphur dioxide from air mixture

showed a greater efficiency than water at 70 deg. and the effluent carried no odor of sulphur dioxide. In later experiments the use of corrugated iron plates in the scrubbers proved to provide an excellent catalytic surface.

In an effort to study thoroughly these catalytic actions, the most favorable conditions for their operation and their application to the problem of gas washing, we have made a great number of tests on salts of copper, zinc, tin, iron, manganese, chromium, cerium, molybdenum and many others. The most promising at present are iron and manganese compounds, the results for which are reproduced in Fig. 1. The laboratory tests were made by passing air containing 0.325 per cent sulphur dioxide at a constant rate through 2 liters of water containing the catalyst. The gas was broken up into small bubbles by passing through a coarse porous plate. The fraction of the gas removed was determined by comparing the time required for neutralization of a known amount of standard sodium hydroxide solution containing hydrogen peroxide in a second tower with that required when no sulphur dioxide was removed. The efficiency of the scrubber was thus determined at short intervals and both the differential and cumulative efficiencies could be calculated.

Your attention is called to several conditions of these experiments: (a) The flow of gas was approximately 0.7 cu. ft. per min. or 1.3 cu. ft. per gal. per min.; (b) the time of contact did not exceed four seconds; (c) the bubbling type of scrubber, such as was used here, is the most efficient in the absorption of oxygen because of the rapid renewal of the liquid film at the gas-liquid interface.[10]

The results of the laboratory work may be summarized briefly as follows:

(a) Both iron and manganese ions show an extremely powerful catalytic effect which is not affected by moderate concentrations of acids.

(b) There is an optimum concentration of the catalysts above which the catalytic effect decreases. Under the conditions of the experiments these concentrations are approximately 1.2 per cent iron and 0.025 per cent manganese (Fig. 2).

(c) In the case of manganese as much as 5400 cu. ft. per gal. of water can be washed with an average efficiency of 92.2 per cent before the differential efficiency falls to 30 per cent. At this time the concentration of sulphuric acid in the liquor is 45.5 per cent.

(d) At the optimum catalyst concentration the effect of an increase in temperature is to decrease the acid concentration at which the efficiency falls. This indicates that the effect of both acid and temperature is due to a decreased solubility of either oxygen or sulphur dioxide, or both, since temperature, in general, increases the rate of a chemical reaction.

(e) Also, at the optimum catalyst concentration, as the percentage of oxygen in the gases is progressively decreased the efficiency is again more susceptible to acid concentration. However, when the sulphur dioxide concentration is decreased the efficiency is less affected by acid concentration.

(f) Definite promoter action is shown when a very small concentration of manganese is added to dilute ferric solutions.

(g) In the case of iron salts as catalysts the capacity of the solution is greatly increased by circulating the solution over scrap iron whereby the concentration of the catalyst is increased and that of the acid decreased.

(h) A number of compounds act as inhibitors to the catalyzed reaction. The most effective of these are the phenols, of which those containing two hydroxyl groups are stronger inhibitors than those containing one. Fig. 3 shows that as little as 5 parts per million of phenol almost completely stops the reaction. Salts of copper and tin also show a negative influence, but in the latter case this is gradually overcome and the original efficiency regained after a time. On the other hand, hydrogen sulphide in the gas shows no effect up to 0.2 per cent but above this concentration it completely in-

[10] Lewis and Whitman, *Ind. Eng. Chem.*, 16, 1215 (1924).

hibits the reaction. Carbon monoxide, hydrogen and a number of other constituents of flue gases have no effect on the catalysts. These inhibiting actions are always much more noticeable in the catalysis by manganese than that by iron salts.

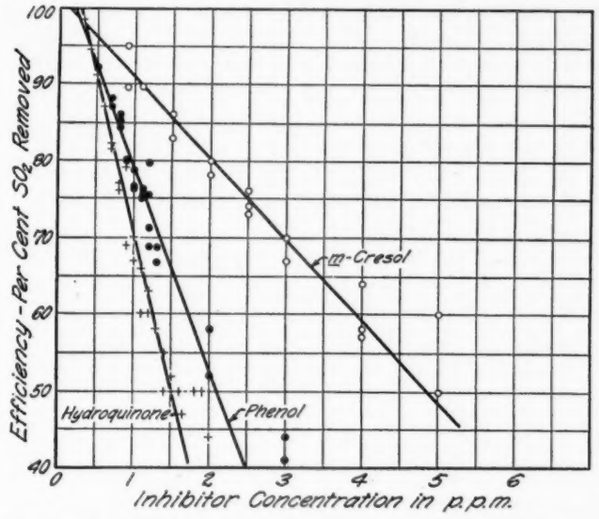


Fig. 3—Inhibiting action of phenols on efficiency of bubble-type washer

It is immediately obvious that the scrubbing of gases with water containing a catalyst involves a complicated series of reactions for which it is necessary to secure considerable fundamental data before designing an efficient washer. For instance, of the three reactions involved, viz., the absorption of the sulphur dioxide, the absorption of the necessary oxygen, and the inter-action of the two dissolved gases, the slowest will control the efficiency of the washing process. In the absence of a catalyst the oxidation must be a very slow reaction, but as the concentration of the catalytic material is increased, the reaction becomes faster and faster until it consumes either all of the sulphur dioxide, or all of the oxygen, or both, as fast as they are absorbed. Any further increase in catalyst concentration not only is unable to produce a higher efficiency but actually decreases the efficiency due to the decrease in solubility of the gases. Furthermore, it is evident that the optimum catalyst concentration must depend on the temperature, the concentration of inhibitors, and the type of washer.

The application of these principles to flue gases was first made with a bubbling-type washer somewhat similar to the one described above, but with the contact time reduced to three seconds. Several interesting facts were determined in these experiments. First, as might have been expected, the lower oxygen concentration in the flue gases increased the effect of the acid so that a somewhat lower acid concentration was finally attained. Secondly, the phenolic compounds from unburned coal-tar constituents in the gases tended to decrease the efficiency of the washer. The curves in Fig. 4 show the results of runs made with 0.025 per cent manganese ions and 0.4 per cent ferric ions, respectively, as the catalyst compared to a run made on the same gases using plain tap water. Evidently, there is a considerable effect due to the contamination by inhibitors. We have made a great deal of effort toward finding a way to eliminate this difficulty and some of our results look very promising at present. It has been a pleasure to find that the contamination is a great deal less when the gases are taken from a boiler equipped with a preheater and operating at a high rating than when they are taken from a smaller, less efficient boiler. Furthermore, in agreement with the laboratory results we found iron catalysts to be less affected by inhibitors than manganese.

As a further development of the problem we have made some attempt to apply our results to a larger scale washer operating on flue gases. It was obvious from the beginning that removal of the sulphur dioxide could be accomplished if sufficient time of contact was allowed. Since, however, this has a direct bearing on the size and the cost of the equipment considerable attention should be given to the design of a washer based on the facts observed in the laboratory and on the modern theories of gas absorption in an effort to decrease the time of contact.

In some preliminary work a small single-effect rotary scrubber was used, having a capacity of 100

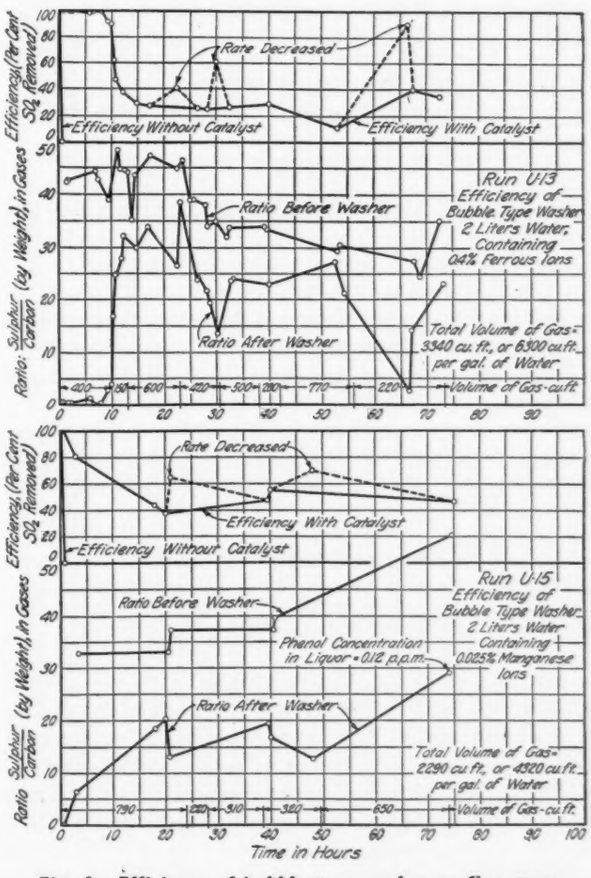

Efficiency (Per Cent SO_2 Removed)
Ratio Sulphur (by Weight) in Gases Carbon
Rate Decreased
Efficiency Without Catalyst
Efficiency With Catalyst
Ratio Before Washer
Ratio After Washer
Run U-13
Efficiency of Bubble Type Washer
2 Liters Water, Containing 0.4% Ferrous Ions
Total Volume of Gas = 3340 cu. ft., or 6300 cu. ft. per gal. of Water
Volume of Gas-cu. ft.
Run U-15
Efficiency of Bubble Type Washer
2 Liters Water Containing 0.025% Manganese Ions
Phenol Concentration in Liquor = 0.12 p.p.m.
Total Volume of Gas = 2290 cu. ft., or 4320 cu. ft. per gal. of Water
Time in Hours

Fig. 4—Efficiency of bubble-type washer on flue gases

cu. ft. of gas per min. On account of the small capacity the water used for washing was recirculated from a reservoir. The pumps, valves, and con-

necting piping were constructed of lead and the washer was lead-lined to prevent the attack of the acid. The flow of water was maintained constant at 8 gal. per min. Gases were drawn from the breeching of the university power plant after the air preheater. Since they were somewhat diluted by leaks in the blower, they entered the washer at about 250 deg. fahr. and having a composition of 5 per cent carbon dioxide, 15 per cent oxygen, 0.1 per cent sulphur dioxide.

The effect of the presence of manganese ions on the capacity of the washing water for absorbing sulphur dioxide is shown in Fig. 5. The initial concentration of manganese was 0.025 per cent, although it was increased somewhat by evaporation. The efficiency of the washer was determined by finding the sulphur dioxide—carbon dioxide ratio before and after the washing. This expedient was necessary in order to eliminate the effect of air leaks between the points of sampling and also the

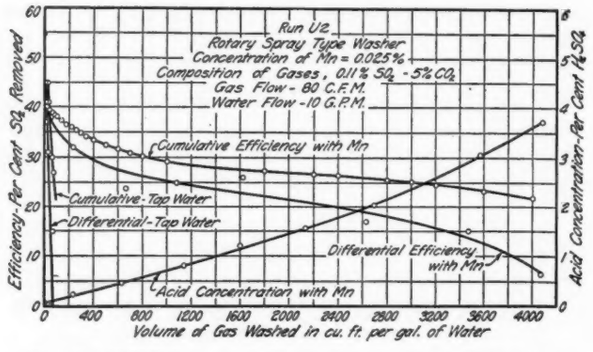


Fig. 5—Efficiency of rotary spray washer on flue gases

effect of fluctuations in the sulphur dioxide content of the gases. Although the efficiency of the washer operating on flue gases was a great deal lower than that of the laboratory scrubber, it compared favorably with that obtained by other large-scale methods. Furthermore, since the time of contact between the gas and liquid in this washer was of the order of only 1/20th second, the great increase in efficiency per unit time is apparent. The results further show that with the catalyst the volume of water required is approximately 270 gallons (1¼ tons) per ton of coal.

Further Considerations

So far in our study we have not given serious attention to the economic side of the problem. It will be impossible to do this until large scale experiments are made. Such problems as the cost of the catalyst, the extent and cost of its recovery and the possible value and disposal of the by-product must first be solved. In this connection we should note that there are only approximately 5 million tons of sulphuric acid consumed in the United States in a year and the production of several thousand tons daily from flue gases would have a drastic effect on the market. Being in the dilute form it could not compete with contact acid and therefore would find its way only into the fertilizer and ammonia recovery processes. The disposal of any excess acid, especially if it must be dumped into streams, will require a serious study, as in many cases our rivers and canals are already overloaded.

The estimates given by the London Power Company on the cost of washing flue gases approximate 36 cents a ton of coal. Much of this is due of course to the large and complicated system of washing. It has been our idea to try to reduce both the time of contact and the volume of water. Whether this can be accomplished feasibly by catalysts remains to be seen. One result which our study has shown is that any method which depends on the oxidation of dissolved sulphur dioxide will be greatly affected by the slow solubility of oxygen. On the basis of very incomplete data we estimate that the rate of absorption of sulphur dioxide even from as great a dilution as in flue gases is over one hundred times as fast as the rate of absorption of oxygen. Obviously the designers of flue gas washers must be influenced by this fact if the oxidation reaction is to be used.

In closing I wish to acknowledge the helpful suggestions and criticisms of Professor D. B. Keyes, in charge of research in Chemical Engineering, and the interest taken by Professor Parr in the progress of the work.

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Lukens Steel Company Founds Industrial Fellowship at Mellon Institute

Dr. Edward R. Weidlein, Director, Mellon Institute of Industrial Research, Pittsburgh, Pa., has announced that the Lukens Steel Company of Coatesville, Pa., has established in the Institute an Industrial Fellowship whose purpose is the scientific investigation of processes employed in the manufacture of steel plates.

Erle G. Hill, who received his professional education at the University of California, has been appointed to the incumbency of this Fellowship. He is a specialist in iron and steel technology who was previously associate professor of metallurgy in the School of Mines of the University of Pittsburgh.

American Standards Association Elects New Officers

Bancroft Gherardi, vice-president of the American Telephone and Telegraph Company, was re-elected as president of the American Standards Association for the year 1932 at the Annual Meeting of the Association held in New York in December.

Other officers, who were also re-elected, are: Cloyd M. Chapman, consulting engineer, United Engineers and Constructors, Inc., New York, vice-president of the American Standards Association and chairman of the ASA Standards Council, and John C. Parker, Brooklyn Edison Company, Brooklyn, N. Y., vice chairman of the Standards Council.

REVIEW OF NEW TECHNICAL BOOKS

Any of the books reviewed on this page may be secured from In-Ce-Co Publishing Corporation, 200 Madison Avenue, New York

Fortune's Favorites

Portraits of Some American Corporations
(An Anthology from FORTUNE Magazine)

THIS book, Fortune's "Peerage of American Business" contains fifteen chapters, or success stories, which appeared in that magazine from time to time. It is written in a vivid and sophisticated but precise style and presents the history and present organization of America's leading companies. In a readable, clever and informative manner it covers the whole trend of American Industry, its trials, tribulations and successes. The reader gets an intimate picture of the inside workings of these famous organizations. He gets a "close-up" as it were of the men who run these companies. Important facts about the growth of the organizations are given, as well as intimate details about the men who are important factors in the companies, their personal inclinations, pastimes, etc. This series of the life histories of the leading American Industries is a fascinating story and should be read for entertainment as well as for information.

The companies included are: American Telephone and Telegraph Company, Swift and Company, Aluminum Company of America, Drug, Incorporated, American Can Company, The Great Atlantic and Pacific Tea Company of America, International Telephone and Telegraph Corporation, R. J. Reynolds Tobacco Company, Allied Chemical and Dye Corporation, Standard Oil Company of New York, The New York Times Company, Bausch and Lomb Optical Company, Niagara Hudson Power Company, The Coca-Cola Company.

Size of book is 6¼ x 9½ inches and contains 350 pages and index. Beautifully printed on old style toned laid paper bound in wine-color cloth. Price $5.00.

The Problem of Fluctuating Loads on Boilers

By G. E. Hider

THE subtitle of this book is "An Investigation into the Characteristics of Different Types of Boilers, their Effect on Production Costs, and the Influence of Thermal Storage Systems." In the preface the author stresses the importance, frequently overlooked in contemporary texts, of *water content* as a factor in boiler efficiency. He points out that under conditions of rapidly fluctuating load such as obtain in many industries, the quantity of steam delivered into the main is often far less than that corresponding to the feedwater entering the boiler and that the difference is a function of the water content of the boiler.

This book should be of interest to those engineers who have found that their coal consumption has been excessive in spite of high efficiency as ascertained in the usual manner. It will also be useful to the many users of small boilers to whom fuel costs may easily mean the difference between profit and loss.

The chapter headings are as follows—Types of Boiler Load; The Effect of Fluctuating Demand; Water-tube Boilers; The Relative Economy of Various Types of Small Shell Boilers; Thermal Storage; Thermal Storage Systems, *Variable Pressure Type*; Thermal Storage Systems, *Feed Water Type*; Thermal Storage in Conjunction with Waste Heat Boilers; Thermal Storage; Feed Water Storage as an Extension of Boiler Water-content; The Marguerre System of Feed Water Thermal Storage.

This book is 6½ x 9 overall and contains 115 pages. Price $3.00.

Symposium on the Effects of Temperature on the Properties of Metals

The A. S. M. E. is cooperating with the American Society for Testing Materials in the publication in one volume of a collection of 27 papers with 200 pages of discussion comprising additional data presented at a joint symposium of the A. S. T. M. and A. S. M. E. in Chicago, June 1931, sponsored by the Joint Research Committee on the Effect of Temperature on the Properties of Metals.

The papers are arranged in two groups, viz:

(1) Engineering Trends and Requirements for Metals at High and Low Temperatures and (2) Properties of Available Metals for High- and Low-Temperature Service.

For the reader who wishes to inform himself only on the general state of knowledge of the subject a specially prepared Summary is incorporated. For those who may wish to go further into the mass of data, an extensive Subject Index has been provided as well as an Author Index.

The book will be ready for distribution February 1st. It will contain 800 pages. Pre-publication price is $4.50. After February 1 the price will be $5.50 to members and $6.00 to non-members of the Societies.

NEW CATALOGS AND BULLETINS

Any of the following publications will be sent to you upon request. Address your request direct to the manufacturer and mention COMBUSTION Magazine

Air Cooled Walls

Catalog No. 161, recently issued by the American Arch Company, describes the application of American Air Cooled Walls to six boiler units varying in size from 216 hp. to 3400 hp. Side elevation line drawings of each of the units are included showing the application of the refractory air cooled walls. The main features of the American Sectionally Supported, Air Cooled Wall are listed and shown graphically in this catalog. 8 pages, 8½ x 11.—American Arch Company, Inc., 60 East 42nd Street, New York, N. Y.

Air Preheaters and Water Walls

Catalog No. 70 describes Edge Moor Water Walls and Air Preheaters. Edge Moor Water Walls are offered in both bare tube and covered construction. Numerous illustrations are included, showing installation progress views of this water wall. The Edge Moor Air Preheater is of the tubular type. Following the section of the catalog devoted to description, there is a section showing typical applications of both the air preheater and water walls. The catalog is very well arranged throughout, is comprehensive, and is exceptional in the quality of its printing and reproduction of its illustrations. 28 pages and cover, 8½ x 11.—Edge Moor Iron Company, Edge Moor, Delaware.

Electrical Instruments

Bulletin GEA-305A, issued by the General Electric Company, features a complete line of pocket-size portable electrical testing instruments for both alternating and direct current. They are suited for general testing and trouble work by industrial plants and central stations. The instruments listed are—Voltmeters, Ammeters, Millivoltmeters, Milliammeters, Combination Volt-Ammeters, Combination Voltmeters-Millivoltmeters—Ammeters, Multipliers and Shunts. The dimensions in inches, approximate weight and list price of each of the instruments are stated. 8 pages, 8½ x 11.—General Electric Company, Schenectady, New York.

Feed Water Treatment

Bulletin BF describes the Paige-Jones Chemical Ball Feeders. Water treating chemicals compressed into hard one pound balls are the material handled by this feeder. The features attributed to this feeder are—quick-opening top permitting opening and closing by hand; the charging opening of the feeder is large enough to permit balls to be dropped in so that charging is simplified; regulation of the chemical feed by means of a regulating plug valve which is set for the rate of solution desired. 4 pages, 8½ x 11.—Paige-Jones Chemical Company, 6216 West 66th Place, Chicago, Illinois.

Fusion Welding

A new catalog entitled "Vogt Homoweld" has been issued recently by the Henry Vogt Machine Company. Homoweld is the trade name adopted for the type of fusion welding described in this catalog. The features claimed for this method of uniting metals are—freedom from all harmful defects such as nitride needles, porosity, cracks, slag, segregations, oxides and other flaws. There are many illustrations showing—welded material before and after destruction tests, photomicrographs showing the grain structure of the weld material at the fusion zone and at short distances from the fusion zone. 24 pages and cover, 8½ x 11.—Henry Vogt Machine Company, Inc., Louisville, Kentucky.

Gas Burners

The Denver Fire Clay Company has recently issued a Bulletin No. 306 describing the DFC Atmospheric Gas Boiler Burners. These burners are designed to burn either natural or manufactured gas. They are adaptable to firing either heating or power boiler units, oil stills and industrial furnaces. The main headings in the bulletin are—Materials and Construction, Operating Advantages, Burner Capacities, How to Select Number and Size of Burners Required. 8 pages, 8½ x 11.—The Denver Fire Clay Company, Denver, Colorado.

Low Head Room Boiler

C-E VM Type Boiler is the name of a new catalog issued recently by Combustion Engineering Corporation. The boiler described is of the bent-tube type and is by design especially adapted to plants having limited space conditions and particularly where the head room is low. The features of this boiler are—large boiler drums; both upper drums have large steam liberating surface; a system of "filter baffles" which stagger the flow of gases around the tubes, thereby promoting heat transfer with but little effect on the draft loss, which is notably low. 8 pages, 8½ x 11.—Combustion Engineering Corporation, 200 Madison Avenue, New York.

Mechanical Stokers

The Stoker Manufacturers Association consisting of 14 of the major manufacturers of mechanical stokers, has recently issued a Condensed Catalog of Mechanical Stokers describing the stokers built by its members. The descriptive matter is confined strictly to engineering facts, presented not as advertising, but rather as authoritative technical information. In addition, the catalog contains interesting data relative to setting heights, stack diameters, heat balance calculations, air requirements for forced draft, stoker application and operation. 40 pages and cover, 8½ x 11.—Stoker Manufacturers Association, Wm. V. McAllister, Secretary, Foot of Walker Street, Detroit, Mich.

Plastic Refractory

The Quigley Company has issued recently a catalog describing its plastic fire brick (trade name Mono-Line). This refractory has many uses in the power plant as it may be employed to build monolithic hearths, bridge walls, front walls and burner ports. It may be advantageously used as refractory fill and backing in water walls of the bare tube type, and is valuable for quick "rammed" furnace repairs. In addition the catalog describes the methods of applying "Mono-Line" and the sizes of the shipping containers. 24 pages, 3½ x 6¼.—Quigley Company, Inc., 56 West 45th Street, N. Y.

Pneumatic Cleaning Systems

Bulletin No. 250, issued by the Allen & Billmyre Company, describes the Tabco Pneumatic Cleaning System. This system comprises a centrifugal exhauster, a separating system, a piping system, a set of cleaning tools and flexible suction hose. This system is particularly adapted for use in central stations, industrial power or steam plants, factories, etc. General data and sectional details of the Tabco System are included. 8 pages, 8½ x 11.—Allen & Billmyre Co., Inc., Grand Central Palace, New York, N. Y.

Recording Thermometer

Bulletin 178 describes the newly developed "Anti-Ambi" recording thermometer manufactured by The Foxboro Company. This thermometer has a compensating device which permits measurement of temperatures at places distant from the instrument, without the ambient temperatures or temperatures surrounding the instrument having any effect on it. Hence the name "Anti-Ambi"—"Ambi" being short for ambient. Features—very sensitive, accurate, has uniform scale and is accurate over the entire scale. 12 pages, 8½ x 11.—The Foxboro Company, Foxboro, Massachusetts.

NOTICE

Manufacturers are requested to send copies of their new catalogs and bulletins for review on this page. Address copies of your new literature to

COMBUSTION

200 Madison Ave., New York

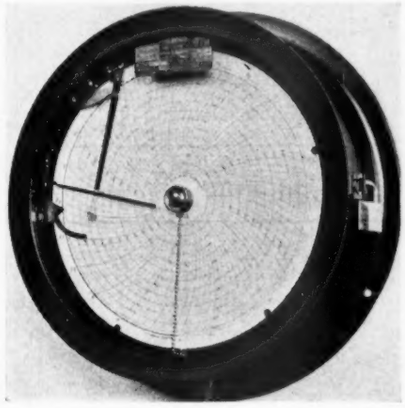
NEW EQUIPMENT

of interest to steam plant Engineers

Anti-Ambi Thermometer

The new "Anti-Ambi" Recording Thermometer, developed recently by the Foxboro Company of Foxboro, Mass., has the following operating features—extreme accuracy and entire freedom from the effects of ambient temperatures (case and tubing temperatures).

This new Recording Thermometer gives *true bulb temperatures* at all times irre-



spective of summer heat or winter cold. The case and tubing may be enclosed in a cabinet and the temperature changed rapidly or slowly up and down for 50 deg. and the pen will remain perfectly steady. The thermometer is designed for use on temperature ranges up to 250 deg. fahr.

The instrument is unique in design in that it does not comprise the conventional cams, compensating levers and bi-metallic strips. It does not employ retarding actions of any kind.

A special feature of the "Anti-Ambi" Thermometer is a sensitive bulb so small that it does not measure over an inch in length. This bulb is located at the end of tubing protruding from the lower part of the instrument shown above.

This instrument is described in the Foxboro Bulletin No. 178. A copy will be sent upon request.

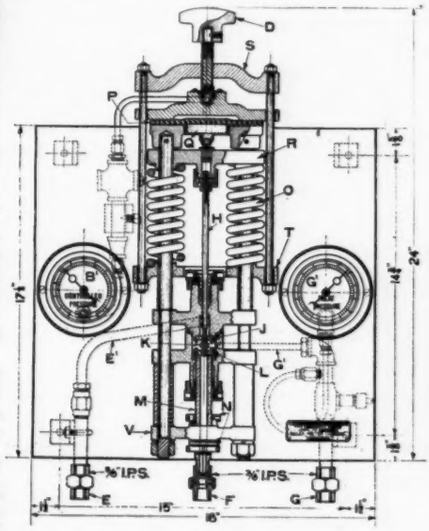
Relay Pressure Valve

One of the latest developments of the Bailey Meter Co., Cleveland, Ohio, is a Relay Pressure Valve known as Style G, which is designed to give extremely accurate pressure control of steam, water or gas lines.

Briefly, the relay valve illustrated, controls the pressure within close limits by regulating the movement of a syphon or piston-operated throttle valve installed in the line in which the pressure is to be controlled.

The controlled pressure is connected to point "B" and serves to actuate the diaphragm "P" against the force of springs "O." A motive pressure of air, water or steam at 50 lb. per sq. in, or over is connected to line "F." Line "G" connects to the syphon or piston-operated regulating valve and line "E" serves as an exhaust. The pressure which exists in line "G" depends upon the position of the diamond valve "K" between the port "L" through which the motive pressure enters and the seat "J" through which the motive pressure exhausts. Assuming that the pressure "B" increases above that for which the relay valve is set, the diamond valve "K" would be moved closer to the seat "L" by the movement of diaphragm "P." This throttles the flow through seat "L" and increases the port area through seat "J," with a consequent decrease in pressure in line "G," which would in turn cause the main regulating valve to close slightly and bring the control pressure back to normal.

Handle "D" is used to balance the force of springs "O" against the controlled pressure "B" which is indicated on the



pressure gage at the left. The relay pressure is indicated by the pressure gage at the right.

Any speed or lag in amplified pressure connection "G" may be obtained. The application of this valve is unlimited.

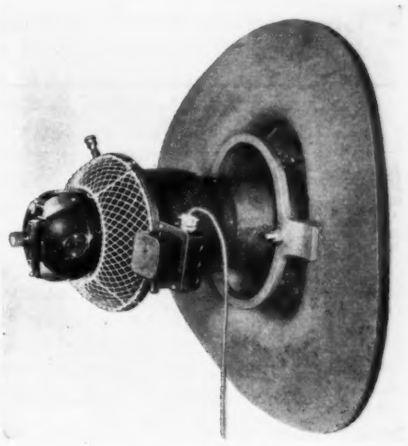
Boiler Manhole Blower

The Coppus Engineering Corporation of Worcester, Mass., announces the development of smaller size Boiler Manhole Blower which they designate as Size No. 150. Although this blower has a capacity of 950 c.f.m. it weighs only 48 lb. exclusive of a detachable manhead and yoke weighing 20 lb. The manhead and yoke on the blower and exhauster will fit manholes 11 in. x 15 in. and 12 in. x 16 in.

This blower unit is driven by a ¼ hp., 110 or 220 volt, universal motor, and can be operated either on a.c. or on d.c. current.

This unit may also be used as an exhauster as it is equipped with a special inlet thimble and motor cooling pipe. The flange on the inlet thimble is identical with that on the diffuser, permitting the machine to be reversed to serve as a blower.

These Blowers and Exhausters are extensively used for rapid cooling and venti-



lating to speed up repair or cleaning of boilers, furnaces, kilns, retorts, cracking stills, coke ovens, dehydrating pots, tanks and similar equipment.

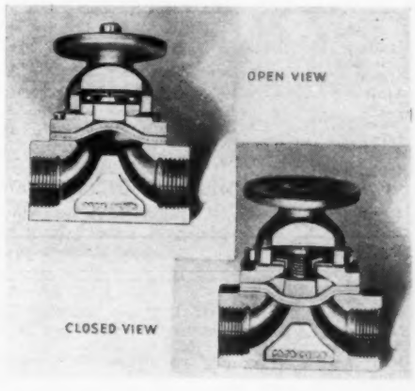
The special feature of this new size is lighter weight, hence convenient portability.

Valves

The Hills-McCanna Company, 2349 Nelson Street, Chicago, have acquired manufacturing and sales rights on a new valve.

This new valve has no metal to metal seats, no stem packing or stuffing boxes. The materials handled never reach the valve bonnet. The diaphragm protects all the working parts from the substances handled. Access to the bonnet or body does not require removal from the line. Corrosion resisting valves of any commercial material are priced in the range of iron valves because the design requires that only the body be cast in special metals.

In the closed position the diaphragm is compressed between the compressor follower and the seat. An even distri-



bution of pressure on the diaphragm is secured through proper design and machining of the seat and compressor.

Literature will be sent upon request.

Boiler, Stoker and Pulverized Fuel Equipment Sales

BOILER SALES

Orders for 672 boilers were placed in October according to reports submitted to the Bureau of the Census by 73 manufacturers.

Month	1930 Number	1930 Square feet	1931 Number	1931 Square feet
January	942	1,081,749	598	576,723
February	873	938,906	516	622,343
March	977	1,263,709	630	664,784
April	1,017	1,070,093	689	825,203
May	1,283	1,329,748	658	603,401
June	1,360	1,588,553	818	677,434
July	1,309	1,410,096	816	687,058
August	1,371	1,356,751	827	594,698
September	1,254	1,282,388	893	692,238
October	1,189	851,525	672	467,375
Total (10 mo.)	11,575	12,173,518	7,117	6,411,257
November	777	709,322		
December	814	587,053		
Total (Year)	13,166	13,469,893		

TOTALS FOR FIRST 10 MONTHS AND NEW ORDERS, BY KIND, PLACED IN OCTOBER, 1930-1931

Kind	1930 No.	1930 Sq. ft.	1931 No.	1931 Sq. ft.	Oct., 1931 No.	Oct., 1931 Sq. ft.
Stationary:						
Total	11,351	11,133,904	6,971	5,934,595	668	465,280
Water tube	975	5,126,016	593	2,506,222	37	153,171
Horizontal return tubular	796	1,075,376	444	562,629	40	56,436
Vertical fire tube	987	300,748	532	143,668	57	14,089
Locomotive, not railway	141	118,111	84	74,920	7	6,239
Steel heating	7,022	3,090,104	4,626	1,992,199	459	168,950
Oil country	914	1,041,713	366	414,845	28	32,480
Self contained portable	393	276,005	268	210,787	35	32,070
Miscellaneous	123	105,831	58	29,325	5	1,845

MECHANICAL STOKER SALES

October stoker sales, reported to the Bureau of the Census by the 21 leading manufacturers, totaled 83 stokers of 20,339 hp.

Year and Month	TOTAL No.	TOTAL H.P.	INSTALLED UNDER Fire-tube boilers No.	Fire-tube boilers H.P.	Water-tube boilers No.	Water-tube boilers H.P.
1929						
Total (First 10 mo.)	1,530	515,140	633	92,962	897	422,178
Total (Year)	1,716	599,585	706	102,515	1,010	497,070
1930						
January	53	13,198	24	2,872	29	10,326
February	73	22,648	26	3,732	47	18,916
March	89	32,403	45	6,128	44	26,275
April	108	35,903	46	6,984	62	28,919
May	96	31,956	41	5,703	55	26,253
June	151	47,803	70	10,100	81	37,703
July	150	37,761	83	11,434	67	26,327
August	115	29,988	61	10,587	54	19,401
September	128	42,899	71	9,186	57	33,713
October	92	38,276	46	5,148	46	33,128
Total (10 mo.)	1,055	332,835	513	71,874	542	260,961
November	71	21,103	41	5,731	30	15,372
December	53	11,726	35	5,307	18	6,419
Total (Year)	1,179	365.664	589	82,912	590	282,752
1931						
January	85	25,902	40	6,719	45	19,183
February	67	14,249	37	5,326	30	8,923
March	63	17,993	27	4,509	36	13,484
April	65	18,723	32	5,192	33	13,531
May	80	23,646	29	4,341	51	19,305
June	111	29,889	55	8,519	56	21,370
July	101	20,735	58	8,283	43	12,452
August	132	31,171	59	8,318	73	22,853
September	96	22,462	56	8,720	40	13,742
October	83	20,339	47	6,566	36	13,773
Total (10 Mo.)	882	224,709	440	66,493	442	158,216

PULVERIZED FUEL EQUIPMENT SALES

October orders for coal pulverizers as reported to the Bureau of the Census aggregated 4 pulverizers having a total capacity of 36,150 lb.

Year and Month	STORAGE SYSTEM PULVERIZERS Total Number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb. coal/hr. for contract	BOILERS Number	Total sq. ft. steam generating surface	Total lb. steam per hour equivalent
FOR INSTALLATION UNDER WATER-TUBE BOILERS							
1931							
January	2	2	..	60,000	1	51,177	704,000
February	1	..	1	40,000	1	29,100	375,000
March	2	2	..	60,000	..	.....	.....
April	2	2	..	60,000	1	34,300	592,000
May	..	..	..	.....	..	.....	.....
June	..	..	..	.....	..	.....	.....
July	..	..	..	.....	..	.....	.....
August	..	..	..	.....	..	.....	.....
September	..	..	..	.....	..	.....	.....
October	1	1	..	30,000	1	11,894	126,000
Total (10 mo.)	8	7	1	250,000	4	126,471	1,797,000
FOR INSTALLATION UNDER FIRE-TUBE BOILERS							
1931							
January	..	..	..	.....	..	.....	.....
February	..	..	..	.....	..	.....	.....
March	..	..	..	.....	..	.....	.....
April	..	..	..	.....	..	.....	.....
May	..	..	..	.....	..	.....	.....
June	..	..	..	.....	..	.....	.....
July	..	..	..	.....	..	.....	.....
August	..	..	..	.....	..	.....	.....
September	..	..	..	.....	..	.....	.....
October	..	..	..	.....	..	.....	.....
Total (10 mo.)	..	..	..	.....	..	.....	.....

Year and Month	DIRECT FIRED OR UNIT SYSTEM PULVERIZERS Total Number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb. coal/hr. for contract	BOILERS Number	Total sq. ft. steam generating surface	Total lb. steam per hour equivalent
FOR INSTALLATION UNDER WATER-TUBE BOILERS							
1931							
January	8	4	4	40,500	9	42,970	412,675
February	2	2	..	8,000	1	7,570	75,000
March	13	13	..	122,000	8	93,960	1,404,000
April	9	8	1	49,250	6	46,300	538,200
May	..	..	..	.....	..	.....	.....
June	14	6	8	59,360	11	56,080	530,290
July	11	8	3	114,600	8	117,000	1,088,980
August	4	4	..	25,000	4	16,725	110,250
September	3	2	1	9,250	3	2,682	86,600
October	1	1	..	2,650	1	3,000	24,000
Total (10 mo.)	65	48	17	430,610	51	386,887	4,269,995
FOR INSTALLATION UNDER FIRE-TUBE BOILERS							
1931							
January	6	..	6	6,000	6	7,500	53,350
February	3	..	3	2,250	3	3,000	22,350
March	2	1	1	2,750	1	3,004	22,500
April	1	..	1	4,000	2	6,700	45,000
May	3	1	2	3,800	3	6,000	27,000
June	4	1	3	4,000	4	5,750	22,100
July	5	3	2	3,900	5	8,000	47,700
August	4	1	3	4,250	4	7,307	43,600
September	4	4	..	4,350	5	5,000	22,500
October	2	..	2	3,500	3	6,000	34,000
Total (10 mo.)	34	11	23	38,800	36	58,261	340,100

Coal Drying for Combustion

(Continued from Page 39)

and about 2 hp. for the driving of the rotary spiders or retarders. Generally also it may be stated that these run at only five r.p.m., so that the wear and tear is extremely small, while the net thermal efficiency—according to the test is 77 per cent, allowing also the final moisture in the coal to be any desired figure from say 0.5 to 5.0 per cent.

Another example of the results obtained with this new drier is supplied by the Emlyn Anthracite Colliery Ltd. of Penygroes, Llanelly, South Wales. There was sent up from this Colliery a delivery of Emlyn washed duff (very small anthracite, being an extremely difficult material), which was put through the Universal drier at the Barrow Colliery, operating at the rate of 12 to 13 tons of coal per hr. The net results of three very careful tests carried out by the officials of the Emlyn Colliery showed that the Washed Duff within a range of 9.53 to 13.10 per cent moisture was reduced to 0.67 to 2.61 per cent moisture, and it was specially emphasized that the volatile content of the coal was not altered. As a result a plant is now to be installed at the Penygroes Colliery, Llanelly, in connection with pulverized fuel firing.

Obviously, we have not yet reached the limit of our knowledge with regard to the design of coal drying equipment, and it will be noted that both these new machines involve extremely small power consumption, reduced floor space per unit of throughput, relatively light weight, low initial temperature of the drying medium, which need not much exceed 250 deg. fahr., and a pronounced tendency to the prevention of dust and the loss of coal in the process of drying.

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Instrument Manufacturers Merge

Announcement has been made of the merging of the Pyrometer Division of the Wilson-Maeulen Company, Inc., with the Foxboro Company. The many users of Wilson-Maeulen Pyrometers will thus be served by a larger, more wide-spread group of instrument engineers.

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All communications relative to Pyrometers should be addressed to Wilson-Maeulen Pyrometer Division, The Foxboro Company, Foxboro, Mass.

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Comment on David Brownlie's Article on Coal Cleaning in Europe

•

Have just finished David Brownlie's able article "European Practice in Coal Cleaning," in your October number.

There is one point that Mr. Brownlie does not bring up, and perhaps he has had no experience with it, due to the comparatively mild climate in England and much of Europe, except Scandinavia, that is, the possibility of washed slack freezing in transit. With some of our northern cities, this possibility is an absolute probability every winter. Some years ago, in a plant on North Water Street in Chicago, I was operating Murphy stokers. On the advice of the builders, we used nothing but washed Spring Valley slack. As you may not be familiar with this, it is the Third Vein (best) coal of Northern Illinois, but is high in moisture and ash, also sulphur, which has no bearing on this story. The ash in the mine run is about 17 per cent and washing reduced this about one half, but we had a spell of zero weather for about ten days and it took five men to mine the coal out of the cars at the plant, to keep the stokers going. As an alternative to shutting down, we bought some unwashed slack, containing about 25 per cent ash, and though everybody predicted that the stokers would not handle it—they did. Since then, to sell me washed slack, will require the services of a salesman who can sell radios to a deaf man.

I'll admit that there are extenuating circumstances. For example, take the Big Dirty seam in Lombard Co., Montana. Here is a fifty foot seam of alternating bands of coal and shale. The coal, what there is of it, is very good and of coking grade, but as mined, it runs about 50 per cent ash. Washing brings this down so that a coke of 18 per cent ash can be made. On the other hand, take the Sunnyside Seam in Utah, or the one at Coal Basin, Colo. Here are two seams each twenty feet in thickness, of coking coal, and a hand glass will not disclose anything that can be washed out of it. At Trinidad, Colo., the coal was first washed before coking, but it was soon found that the coke would not bear the burden, so washing was discontinued. These coals are all of low moisture content when mined, but in the Mid-Continent field which includes Illinois, Missouri and Iowa, the coal will run 15 to 20 per cent moisture when mined, so when washed, unless given time to dry thoroughly, the slack may have over one-fourth water on which cost, freight and handling has to be paid, which with stokers, is simply substituting one loss for another, with the additional disadvantage of freezing in severe weather.

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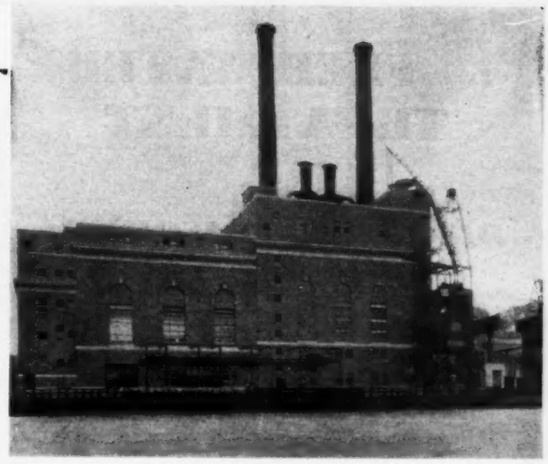

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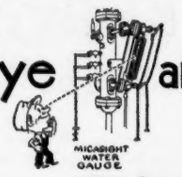
By Eye  **and by Ear**

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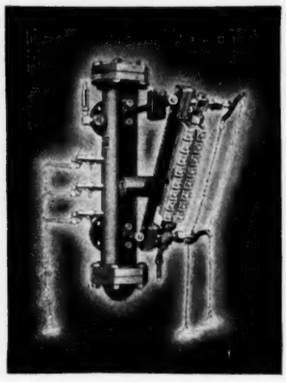

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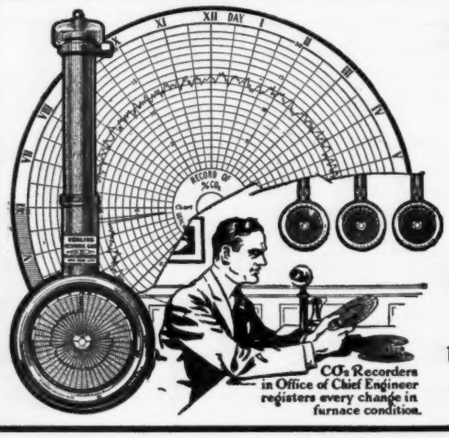

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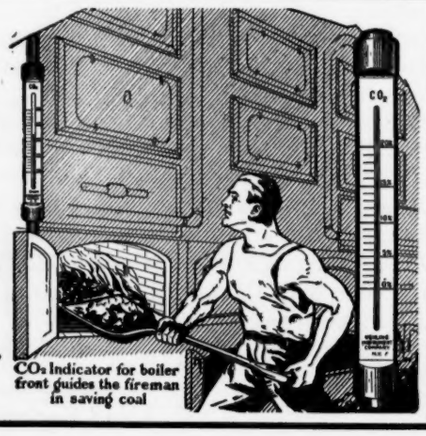

CO_2 Indicator for boiler front guides the fireman in saving coal